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ABSTRACT

This document contains the transcript of a senate hearing on the crisis in science and math education. The document includes the opening statements of Senators Glenn, Kohl, Bingaman, Lieberman, Heinz, and Sasser, and the testimony of seven witnesses including: Honorable Mark O. Hatfield, Senator from the State of Oregon; Carl Sagan, Ph.D. Cornell University; F. James Rutherford, American Association for the Advancement of Science; Bill G. Aldridge, National Science Teachers Association; Philip Uri Treisman, University of California at Berkeley; Betty M. Vetter, Commission on Professionals in Science and Technology; and Shirley M. Malcolm, American Association for the Advancement of Science. Appendices include the prepared statements of witnesses, pertinent articles, charts, and a statement from the National Society of Professional Engineers. (CW)

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CRISIS IN SCIENCE AND MATH EDUCATION

HEARING

BEFORE THE

COMMITTEE ON GOVERNMENTAL AFFAIRS UNITED STATES SENATE

ONE HUNDRED FIRST CONGRESS

FIRST SESSION

NOVEMBER 9, 1989

Printed for the use of the Committee on Governmental Affairs

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CRISIS IN SCIENCE AND MATH EDUCATION

THURSDAY, NOVEMBER 9, 1989

U.S. SENATE,
COMMITTEE ON GOVERNMENTAL AFFAIRS,
Washington, DC.

The Committee met, pursuant to notice, at 9:30 a.m., in room SD-342, Dirksen Senate Office Building, Hon. John Glenn, Chairman of the Committee, presiding.

Present: Senators Glenn, Nunn, Bingaman, Kohl, Lieberman, Roth, and Heinz.

OPENING STATEMENT OF SENATOR GLENN

Chairman GLENN. The hearing will be in order.

Twenty-five years ago Lyndon Johnson, who had been a former school teacher himself of course, said, "We have entered an age in which education is not a luxury permitting some people an advantage over others. It has become a necessity without which a person is defenseless in this complex, industrialized society."

I believe that is truer today than ever before. In fact, I believe that science education in particular has a role to play in, as another educator put it, "making it possible for children not to be foreigners in their own culture."

Interestingly enough, the last time the United States devoted any attention to the quality of math and science education was in the wake of the Sputnik launching. And now, 30 years later, the United States again faces a crisis in science and mathematics education.

Now, why should this concern us? I suppose we think the answers are obvious, but the United States now operates in a global market that places a high premium on technological innovation. When the United States was a colonial village, as it once was back in the earlier days, it made little difference whether or not anybody even came through that particular town from one year to the other, because the cobbler was on one street, the buggy maker was on another, and the cabbage grower was just at the end of the village.

Then we went to where the cabbage growers were in the Imperial Valley in California, the cobblers were in New England and parts of the South, and the buggy makers were in Detroit. And now we have gone to where the buggy maker is 25 percent Japanese. We don't even make shoes to speak of in this country any more—they come from Korea and Italy, and we send hundreds of millions of tons of food all other the world.

The United States exists in a global community now. We may not like that sometimes. The long term competitiveness of this country will require that we outcompete other nations around this world in education and in basic fundamental research. Those two things were hallmarks of why we developed the way we did.

More than 70 percent of the goods manufactured in the U.S. now compete with merchandise made overseas. Consider also our staggering trade deficit, the very measure of U.S. competitiveness overseas. How is this country going to be able to compete with our trading partners if we cannot produce the scientists, the engineers, the technicians necessary to make internationally competitive products? And if we cannot compete in the global market, how are we going to provide good jobs for our citizens, or generate the tax revenues to help clean up the environment, fight crime, provide health care, or defend the country.

Today you are will hear that too many of our young people are illiterate in both science and mathematics. You will also hear that this country may not produce enough scientists, engineers and technical personnel to meet the demands of our industrialized high technology economy. Every new report on American education produces another horror story that has to make you wonder: how did we ever let it get to this?

The same Nation that landed a man on the moon and returned him safely to earth educates fewer than one out of every five high school graduates in the laws of physics. The same Nation that has produced more Nobel Laureates in chemistry than any other Nation lets half of its young people graduate from high school without taking a single course of any kind in chemistry.

And finally, American school children are routinely outperformed in international comparisons of science and math performance by students from our chief trade rivals. In fact, this country graduates 700,000 young people every year that are functionally illiterate.

Declining birth rates and interest in scientific careers among young American people, plus increasing numbers of students from groups traditionally underrepresented in science and engineering, namely minorities and women, portend an almost certain shortage of scientific personnel.

Science and math education is critical to U.S. economic prosperity. Our factories and laboratories will need a first rate technical work force, and we must overhaul science and math education in this country if the next generation is to prosper in an increasingly competitive world.

First, we need national leadership to focus attention on the quality of science and math education. That is why Senator Hatfield and I introduced Senate Concurrent Resolution 52 that declares science and math education a national priority. Moreover, the President and other public officials should use their bully pulpits to raise the stature of educators, scientists and teachers in our society.

Even modest gestures, I think, are called for. They may bear fruit. Just as an example, I think the public would begin to get the message if the President—any President, Democrat or Republi-

can—spent as much time appearing on television with teachers and Nobel Laureates as they do with Super Bowl champions.

For my part, I have proposed that the National Science Foundation award Congressional scholarships for science, math and engineering to two high school seniors from every Congressional district in the country. My bill, S. 134, is important not only because it would produce a thousand kids a year better educated in the sciences and math, but it also sends a very important symbolic gesture. These scholarships send a message to our young people that scientists are important to our economy and our national security.

Scholarships, or even trips to the White House, by themselves will not eradicate science illiteracy or close the leaks in the technical pipeline.

To accomplish that we must look to the beginning of the education pipeline for the source of the problem as well as the solution. One of the greatest obstacles to getting more young people—especially female and minority students—interested in a technical career are the science and math courses themselves. Luckily, private efforts are underway all over this country to rewrite, reform and reinvigorate science and mathematics curriculum. It is my goal to make these developments available to all schools and all teachers.

This month Senator Hatfield and I will be introducing legislation that would bridge the gap that now exists between the Ivory Tower, laboratory-like settings where science as math curricula are frequently developed, and the real world out there where it is taught. Our regional consortia would bring state of the art science and math curriculum to the attention of the Nation's classroom teachers.

Senator Hatfield and I will also propose the establishment of a National Clearinghouse for science, math and technology education materials. Its goal: to provide a central library and a database of the Nation's model science programs.

Now, I'll close my opening remarks by quoting one of America's greatest writers, and interestingly enough, a person who had very little formal schooling. He said, "Out of the public school grows the greatness of the Nation."

It was no joke he was trying to make at that time. The man was Mark Twain, of all people. "Out of the public school grows the greatness of the Nation."

If that isn't as true today as it once was, then we have let our young people down. Somewhere along the way our generation forgot what made this country stand apart from others. We now have the responsibility to prepare succeeding generations to be able to excel in an increasingly technological culture, and it is our burden to repair the schools.

So, that is a rather lengthy opening statement, but I think it sets the stage for the experts that we have here today.

Senator Kohl?

OPENING STATEMENT OF SENATOR KOHL

Senator KOHL. Thank you, Senator Glenn. We all commend you for calling this hearing, because we all care deeply about the

future of science and math education in our country. Obviously, there is nothing more important to our future than the education of our young people. The failure to reach our young people through education has reached nightmare proportions right here in our own city of Washington, D.C.

What do we read about our young people most? That they are dealing death to each other with bullets and with crack. And yet the economy of the Washington area is booming. There are thousands of jobs available out there. Unfortunately, these kids just aren't being prepared to get these jobs. They don't have the math, science or technological skills. They aren't learning the skills, and saddest of all, we are losing out on their potential.

There are young people out there cutting raw cocaine with chemicals from the local hardware store. They are manufacturing new highs and new products by soaking marijuana in ever changing agents, and each of these new drugs is more addictive, more deadly, and less costly than the last.

How is it that we have failed to tap that ingenuity, that sense of experimentation? How is it that these kids who can measure grams and kilos and can figure out complex monetary transactions cannot pass a simple math or a simple chemistry test?

With the right kind of education, these streetwise kids who are building marketplaces out of their neighborhoods could be contributing to cleaning up our environment. They could be developing chemicals that save life instead of chemicals that take life. And they could be working with large database computers instead of dropping quarters into arcade games or pushing cartridges into Nintendos.

With jobs in high technology firms they might even lead the way to a new future for themselves and for our country. With the right skills there is a whole world of opportunity that doesn't involve the life and death risks of the drug market, and they can make a decent and honest living.

But this is not a problem that is limited to urban areas like Washington, D.C., nor is it confined to any socioeconomic group. The stats we have all heard so much about tell us that the problems of math and science education goes beyond the issue of the disadvantaged. Even the high school students who do best in the United States rank poorly compared with other countries, so it is not just the poor kids, but all of our kids who need better science. We have to boost our best to meet the increasing demands of a changing global society, and the classroom is the best launch vehicle available to lift our kids and our country into the future.

And so it is very appropriate, very meaningful, very important that we have these hearings here this morning, and I'm looking forward to hearing testimony and asking questions.

Thank you very much, Mr. Chairman.

Chairman GLENN. Thank you. Senator Bingaman, do you have any remarks?

OPENING STATEMENT OF SENATOR BINGAMAN

Senator BINGAMAN. Thank you, Mr. Chairman. I do have a statement I will put in the record.

Let me compliment you on holding this set of hearings. We are 7 weeks from a new decade, and it is entirely appropriate that once again we try to reinvigorate the Nation's attention to education, and in particular, science and math education. Your comments about how public officials, the President and others could do a great deal by merely highlighting the importance of teachers and Nobel Laureates in our society, rather than Super Bowl champions, was excellent.

My father taught college chemistry for 45 years, and he always liked to say that "Football is to education as bull fighting is to agriculture." And I think that is another way of saying the same thing. I appreciate the chance to be here and look forward very much to this excellent testimony.

[The prepared statement of Senator Bingaman follows:]

PREPARED STATEMENT OF SENATOR BINGAMAN

Mr. Chairman, I want to commend you for holding this hearing today and for bringing together such an impressive and knowledgable group of witnesses. The experts we will hear from today have much to teach us, and we in the Congress would do well to listen carefully to them and heed their advice.

We must listen and, more importantly, we must take action. We must take action because if we do not—if we continue to ignore the warning shots that are exploding all around us—our nation will suffer such damage that it likely will never recover.

Without question, the need to improve our nation's science and math education system is urgent and important. We simply must give a higher priority to remaining a world leader in science, engineering and technology. And we cannot do this without giving an equally high priority to the education of our children.

I. THE SCIENCE AND MATH CHALLENGE

The importance of science and technology in our modern world is indisputable. When the history of the 20th century is written, I believe it will be recorded as the century in which science and technology dramatically and permanently altered the lives of all of mankind.

None of us exaggerates when we say that the nations that lead in science and technology will inevitably lead economically and militarily as well. It follows that the nations which fall behind in science and technology also will fall behind economically and militarily.

But it is important to remember: a country that leads in science does not simply produce Nobel laureates. That is only part of the measurement of success.

A country that leads in science must also lead in applying new scientific knowledge—in putting new technology to use. And for a country to lead in applying science, it must have a reasonable level of general scientific competency within its entire population.

Mr. Chairman, given that we all agree on the importance of science and technology to our nation's future economy and future security, I believe that we must begin to seriously address some obvious questions:

How are we doing?

Are we still preeminent in these fields?

Are we doing what we should to maintain a leadership position?

Unfortunately, the answers to these basic questions are not encouraging.

We are no longer preeminent in many key fields of science. We are not taking the steps we need to take to maintain a leadership position.

In his book, "The Business of Science," Simon Ramo traces our country's performance in science and technology over the last three decades.

In the 1960s, Ramo writes, scientific preeminence was a major national goal. By the end of the decade, few doubted that the U.S. led the world in virtually all areas of scientific discovery and invention. The launching of Sputnik by the Soviets and the national commitment to send a man to the moon were major factors in our drive for preeminence.

Throughout the 1970s, we continued to lead. But by the beginning of this decade—the 1980s—our lack of priorities and our complacency with previous successes began to take their toll.

And as the 1980s draw to a close, Simon Ramo's assessment of our position is sobering. He states, as so many others have also stated:

"In recent decades the United States has lost its position as global champion in technology and has become an average performer, winning some contests, but losing more."

What has happened?

Part of what has happened is that the focus on science, engineering, and technology, which characterized public sentiment in the 1960s, has been lost.

We have an inherent belief, as Ronald Reagan said so often during his presidency: "Given a level playing field, Americans can out perform and out compete anyone in the world."

Unfortunately, we have allowed this self-confidence to persuade us that, unlike other nations, we do not need to set national priorities or goals. We do not need to make plans to achieve our objectives.

We falsely believe that being the world leader is our birthright. We leave the planning and hard work to others.

It is time to forget about birthrights and to work for what we deserve. Just as our parents and grandparents worked to make this country great, so too must we work. We must once again focus on creating and improving the technological base needed to be a world-class economic power.

II. THE SOLUTION

I am hopeful, Mr. Chairman, that today's witnesses will help us sharpen that focus. The Congress needs this assistance because I believe it will be left to us—the members of the House and the Senate, together with the states—to take up this task.

I hope I am wrong, but I do not believe we can realistically expect the administration to do much of what needs to be done.

In fact, during this decade, the greatest failure of leadership we have experienced in science and math education has been within the administration.

As you recall, this decade began with Ronald Reagan's pledge to abolish the U.S. Department of Education.

The position clearly was that federal involvement in education should be terminated, or at least substantially diminished. And it was.

I hope that we can turn this trend around. With your guidance, Mr. Chairman, and with the help of experts like those gathered in this room today, I believe we can turn this trend around. We can recreate a system where the federal government will once again work in partnership with states to help meet the challenge to succeed in the sciences.

Indeed, we can already point to some successes. In my home state of New Mexico, for example, a "Science and Technology Alliance" has been forged between educational institutions and our national laboratories.

Through the Alliance, New Mexico's Highlands University and Luna Vocational-Technical Institute have joined with Los Alamos and Sandia National Laboratories to pursue a program sponsored by the Department of Energy that will help increase crucially-needed minority representation in the Department's scientific and engineering programs.

Another success in New Mexico is the establishment and invigorating continuation of the "Centers of Technical Excellence" at three of the state's universities.

But clearly, we cannot stop there. We must strive for more. I believe we all should be working toward four basic steps, and I would be interested in the witnesses comments about these "core steps."

First.

We need to develop a better method for measuring and assessing the condition of science and math education nationally and among individual states, from year to year.

Throughout a recent set of hearings on the quality of our nation's education information and statistics gathering efforts, which I chaired in my capacity as chairman of the Governmental Affairs Subcommittee on Government Information and Regulation, I have been struck by how incomplete and fragmentary our informational base is.

We need to know the level of effort in each school.

We need an objective appraisal of how much our students are learning from year to year.

Most importantly, we need to know the condition of our teaching force, which is given the difficult task of instructing our children in these subjects.

Second.

We need to set some realistic, but ambitious, goals for the next 10 years and beyond. After determining where we are today, we need to set goals—not only to increase basis knowledge of math and science, but to really help students who will pursue careers in these fields.

Nationwide, of every 1,000 young people who will graduate from college this year, only about seven will pursue a career in science or engineering.

In Germany, the figure is 25 out of 1,000.

In Japan, it is 40 out of 1,000.

It is no wonder that we are losing ground in our competition with those nations.

Third.

We need to improve funding for the teaching of these vital subjects. We need to ensure adequate salaries for the people who do that teaching.

Fourth.

We need to continue developing innovative ways for our students to benefit from the scientific talent and the tremendous research activity that exists throughout our country, in every state.

The legislation you propose, Mr. Chairman, will go a long way toward reaching this goal. We simply must coordinate federal education efforts and network our resources. I strongly support your legislative suggestions to convene an interagency committee of federal "mission agencies" to coordinate science, math, and technology education at the federal level and to establish regional networks of consortia to provide schools with vitally-needed assistance as they undertake critical reform efforts.

III. CONCLUSION

Mr. Chairman, I am well aware that setting goals and priorities sparks argument. Some will agree with the priorities I have briefly described. Others will disagree.

But the alternative to setting these priorities is unthinkable. It is to continue to drift. It is to continue to assume that we will remain a world leader without making the kind of concerted effort other countries around the world are making. Or it is to assume that maintaining a leadership position in these fields is not important to our country's future.

I reject all of these suggestions.

I believe our country can meet the challenge. I believe we can be a leader in the ongoing "scientific revolution."

We can be a leader if we seriously commit ourselves to working persistently and creatively toward this national goal. With the guidance of those here today, I am confident that we will achieve our goals. Thank you.

Chairman GLENN. Thank you. Senator Lieberman?

OPENING STATEMENT OF SENATOR LIEBERMAN

Senator LIEBERMAN. That's a tough one to follow, Mr. Chairman.

I also thank you for convening these hearings, and may I say it seems particularly appropriate, historically, that you are taking the lead in directing the attention of the Congress and the people of the United States toward the gaps that we have in science and math education. The last time we were faced with this sense of a technical and scientific gap in our knowledge was after the Soviets launched Sputnik. And you, obviously, were at the lead in America's response to that challenge.

Today probably for the first time since then I think we have a growing sense of our science and math illiteracy and the way in which it affects our international standing. When Sputnik went up we were terrified because of what it said about our ability to compete with the Soviets militarily. Today we are beginning to be alarmed—although there has not yet been anything quite like Sputnik to jar us into action—about our ability to compete economically in the world, particularly with the reborn nations in Asia and Europe.

I thank you for your leadership and I hope as you led us out of that crisis you will lead the Nation from the United States Senate out of the one we are in now. The reality is that the American people understand the threat. I'm sure you saw the poll that came out this summer—I, frankly, forgot who did it—that said that more Americans were worried today about the threat of economic competition from Asia than they were about the threat of military competition from the Soviet Union.

While there are many things that we have to do as a Nation to better compete and maintain our economic predominance in the world, such as increasing new investment and increasing savings and increasing motivation, clearly one of the things we have to do to compete economically in the world is to increase our level of science and math and technological awareness.

I have a statement that I would like to include in the record which documents the various sad statistics of how poorly we do relate to the other industrialized nations of the world in our science and math ability. I'm reminded of something that President Johnson said, Mr. Chairman, which is that "We must open the doors of opportunity but we must also equip our people to walk through those doors."

I think Senator Kohl has very accurately documented the fact that there are many doors of opportunity open in this country but we are not equipping our people to walk through them. I hope out of these hearings we can come up with some ideas about how we might better accomplish that and better maintain our economic strength and thereby the basic standard of living of most American families.

Thank you.

[The prepared statement of Senator Lieberman follows:]

PREPARED STATEMENT OF SENATOR LIEBERMAN

Mr. Chairman, not since the post 1957 launch of the Soviet Sputnik, has there been such an intense focus placed on the decreasing "technical and scientific literacy" of this country's young people. In 1957, the focus was the result of a contentious cold war relationship with the Soviet Union. In 1989, we find ourselves with a similar focus, but this time as the result of the declining ability of the United States to compete in the global marketplace.

Mr. Chairman, economists and economic indicators suggest that the United States may be losing its global economic predominance, and many associate this deterioration with the decline of our educational system. For more than 25 years the United States has experienced a lower rate of productivity growth in manufacturing than Japan, West Germany, the United Kingdom and other European countries. Similarly, in recent years, U.S. students have been out performed by students from Japan, West Germany, and the United Kingdom in virtually every major assessment of science and mathematics educational achievement.

We must recognize that excellence in education is the foundation of economic growth. I vehemently agree with those who argue that a greater commitment to research and development, an increase in the national savings rate, and elevated levels of investment are all indispensable components of expanded productivity, but we cannot hope to improve our global competitiveness without first addressing the training and preparation of our future scientists, physicists, chemists, and engineers.

A recent survey by the National Science Teachers Association, which is represented there today, concludes that "of the 24,000 high schools in the U.S., 29.6 percent offered no physics courses; 17.5 percent offered no chemistry; and approximately 8 percent offered no courses in biology." Additionally, surveys suggest that only "60% of U.S. students take biology, 30% take chemistry, and only 15% take physics".

In mathematics, the National Research Council reported that "non-U.S. citizens who take the Graduate Record Examination in mathematics average 100 points higher than U.S. students, and that the mathematics achievement to the top 5% of twelfth grade students is lower in the United States than in other industrialized nations." The average twelfth grade mathematics student in Japan out-performs 95% of comparable U.S. twelfth grade students.

Although not directly related, I recently read an article in which the author commended a high school for being the first public school in Connecticut to add a sequential Japanese program to their permanent curriculum. Next year, according to the article, officials hope to expand it to a two year program. Programs like this should be the norm, not the exception, if we are to compete in the global economy.

In order to improve our students educational achievement, particularly in the areas of science and math, we must look at our entire educational system. We must review the curriculum, the instructors, and the ways in which we motivate students, especially those students who are most likely to drop out or otherwise ignore educational opportunities.

It is alarming to think of what is in store for the future when estimates suggest that only .2% of the class of 4 million high school sophomores from 1977—just 9,700 students—will receive doctoral degrees in science and engineering in 1992. There must be a way to keep more than .2% of our students in the "science and engineering pipeline", as it is often called.

Finally, Mr. Chairman, President Lyndon Johnson once said that "we must open the doors of opportunity. But we must also equip our people to walk through those doors." We spend a lot of time deliberating on growth and opportunity, but we rarely consider the requisite components necessary to achieve such growth. Clearly, excellence in science, math, engineering and technology is an indispensable part of that formula.

Chairman GLENN. Thank you much. Senator Heinz, any comment?

Senator HEINZ. Mr. Chairman, thank you. I have a statement which I would ask unanimous consent be put in the record.

Chairman GLENN. Without objection it will be entered in the record.

OPENING STATEMENT OF SENATOR HEINZ

Senator HEINZ. I certainly join our colleagues, Mr. Chairman, in commending you on holding this timely hearing. I will not take a lot of time except to observe that most of us share the concern expressed by the Senator from Connecticut, Mr. Lieberman and others about the ability of this country to compete. To oversimplify it somewhat, there are three factors above all—an economist will tell you—that are going to determine this country's ability to be competitive. They are labor, management and capital. These three factors when multiplied together give you economic success or failure, depending on what the particular inputs are.

In terms of labor, there are really two components that determine productivity. One, of course, is intangible—motivation or attitude—and the other is education. In our increasingly technical world there is nothing more important than having technically trained minds. In order to make it possible for this country to be for all intents and purposes effective in international competition, we must begin educating our young people, technically, at an early age—if not we are at risk of losing a great deal of human capital potential.

So I think this subject is essential and vital and I am delighted you are holding it.

[The prepared statement of Senator Heinz follows:]

PREPARED STATEMENT OF SENATOR HEINZ

Mr. Chairman, I am pleased to join you this morning for this hearing on science and math education.

It is rather sobering, Mr. Chairman to add up the recent findings from a variety of studies and reports assessing the critical thinking and technical skill level of today's students. All of us here undoubtedly concur that we have before us an alarming scenario.

The numbers discouragingly illustrate our Nation's deficit in the critical technological areas reflecting most Americans are mathematically and scientifically illiterate:

NATIONALLY

More than one-quarter of 13-year-olds fail to demonstrate an adequate understanding of the content and procedures in elementary school math. [*Crossroads in American Education*, 2/89, Educational Testing Service]

In science classes, 41% of 11th graders and 60% of 7th graders report never being asked to write up a science experiment independently. [*Crossroads in American Education*, 2/89, Educational Testing Service]

Of the Nation's 24,000 high schools, 29.6% did not offer physics courses; 17.5% did not offer chemistry classes, and 8% did not offer biology course. [National Science Teacher Association, 1986.]

3 out of 4 Americans stop studying math before completing career/job prerequisites. [*Everybody Counts*, 1989, National Research Council.]

Few youngsters can use math to solve everyday problems. [*The Mathematics Report Card*, National Assessment of Educational Progress (NAEP), 6/88]

INTERNATIONALLY

The top 5% of American math students score at the Japanese average. ["Time for America to Set National Education Norms" by Dennis P. Doyle. *LA Times*. September 10, 1989]

In Korea, 78% of 13-year-olds can use intermediate math skills to solve two-step problems compared to only 40% of their counterparts in the U.S. [*A World of Differences*, Educational Testing Service, January 1989]

40% of Korea's 13-year-old students understand measurement and geometry concepts and are successful at solving even more complex problems. Less than 10% of those from the U.S. have the same skill level. [*A World of Differences*, Educational Testing Service, January 1989]

More than 70% of the 13-year-olds in British Columbia and Korea can use scientific procedures and analyze scientific data, while only 35–40% of their peers in the U.S. demonstrate the same degree of competence. [*A World of Differences*, Educational Testing Service, January 1989]

Students in the United Kingdom report the most hands-on science experiments and those in the U.S. report the least involvement. [*A World of Differences*, Educational Testing Service, January 1989]

This situation is only exacerbated by the fact of our vastly changing, high-tech global market place. The future of prosperous economic growth and our Nation's position in world markets will be determined by our ability to provide intelligent leadership in analytical and technological fields.

In addition to this, America demographically is experiencing and will continue to experience a feminization of our workforce. Immigrants and minorities will also make-up a greater share of the labor pool. In light of this transformation our educational system must be equipped to meet the challenge of providing the necessary skills to reach all those to be integrated into our workforce.

Responding to our Nation's technology skill deficit will need a multifaceted approach on all fronts including Federal, state, school district leaders, local schools, and educators.

Within Pennsylvania, I have discovered one such math initiative which I want to highlight this morning for their fine efforts.

Dr. Regina Brunner and Charles Chapman, math educators at Cedar Crest College in Allentown, Pennsylvania have designed a very successful grass-roots program to encourage seventh and eight grade girls to study math and to assist their teachers in dealing with the technological explosion in the classroom.

Cedar Crest, an independent liberal arts college with a proven track record in encouraging women to pursue math-related careers became rightly concerned with our Nation's overall declining interest in math. This decline is illustrated by the fact

that in 1970 more than 1,000 Americans earned doctorates in math. By 1988, the figure had plummeted to les than 400. Also, between July, 1986, and June, 1987, fifty-one percent of the doctorates in math awarded in the United States were awarded to foreign students.

"MathConn" is the innovative program developed by Cedar Crest College. "MathConn" represents a two prong solution to focus on the changing teaching methodology in math, and to bring more women into the equation. Cedar Crest College is an ideal institution because of the proven track record it has in the area of math and related studies. While the number of students majoring in math and related fields has declined nationally during the last 10 years, the number of math and computer science majors at Cedar Crest has increased.

"MathConn 89" was successful in reaching more than 200 seventh and eighth grade school girls and their teachers from 36 schools. The students met in small groups to learn about math-related careers and improve their skills through problem discovery sessions. During the same time, their teachers learned about the use of technology in the classroom and motivational math techniques for use in the classroom.

In light of the success of "MathConn 89", plans are well underway for "MathConn 90" with an increased number of participants. Community initiatives, such as "MathConn" will contribute greatly to increasing the math and related skills of our young people. I complement and commend Cedar Crest College on the responsible leadership with this program to address the needs of our ever expanding technology-oriented learning environment and workplace.[1]

Educational reform efforts supporting our scientific enterprise need to occur at all levels, Federal, state and local. Such initiatives must prove equal to the challenges of our high-tech, information era.

Mr. Chairman, I look to the comments of our distinguished panelists for their expert insight as to how we can energize our learning enterprise for the education of this Nation's future pool of scientists and technicans.

Chairman GLENN. We also have a statement from Senator Sasser, who could not attend this morning, to be placed in the record at this time.

[The prepared statement of Senator Sasser follows:]

OPENING STATEMENT OF SENATOR SASSER

Mr. Chairman, Members of the Committee and distinguished guests, I want to thank my colleagues, Senator Glenn and Senator Hatfield for their leadership in this critical area.

The future of Tennessee is directly tied to our ability to win the battle for scientific and technological competency. Agriculture is our largest industy. Farming is a $3 billion business in Tennessee. In 1985, Tennessee's agricultural experts were more than $300 million. Farming and agribusiness has been revolutionized by technology in my lifetime. We continue to struggle to conduct our farming business in a way that is productive, cost efficient, safe and environmentally sound. Success in all of these areas depends on competency in science, math and technology.

Tennessee is also a state with a heavy investment in applied technology in manufacturing. In Middle Tennessee we have Nissan, Saturn and Ford Glass. In East Tennessee we have Alcoa Industries and Eastman Kodak. From Memphis, Tennessee, Federal Express manages a worldwide network.

Important scientific and technological innovators have their home in Tennessee. Oak Ridge National Laboratories and the Tennessee Valley Authority are among the best known.

We are proud of the Tennessee men and women who make up the workforce for these great industries. We are hard at work in Tennessee to strengthen our educational system to meet the needs of our students and our economic future. Concentration on "getting it right the first time" in the primary grades has resulted in continuous improvement in science and math standardized test scores. In 1989, Tennessee second graders scored in the 76th percentile in math computation, and 65th in math application on the Stanford test. We are striving to improve across the board.

I welcome the testimony of these distinguished witnesses. I thank you for taking the time to come today and lend your considerable expertise to these proceedings.

Thank you Mr. Chairman.

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[1] See three articles starting on p. 115.

Chairman GLENN. Thank you much. Our first witness this morning will be Senator Hatfield.

Senator, we welcome you at the hearing and, in fact, after your testimony if you wish to join us up here on the podium and be part of the Committee, why we would welcome you to do that.

I want to thank Senator Hatfield for appearing. If it sounds, from what I said earlier, as though he and I are singing from the same hymnbook, I think there is a reason for it. We have been working together on this issue since last spring. I am proud to be a original cosponsor of his resolution declaring science and math education a national priority. And even more important than that, I feel we have been working very hard on our major science and math education initiative. And he and I both feel that we have a proposal that could make a real difference.

So I want to commend him for his very interest in education and his leadership on this issue. Thank you, Mark, and we look forward to your testimony.

TESTIMONY OF HON. MARK O. HATFIELD, U.S. SENATOR FROM THE STATE OF OREGON

Senator HATFIELD. Thank you very much, Mr. Chairman. I would like to have my statement placed in the record.[1]

Chairman GLENN. Without objection, so be it.

Senator HATFIELD. Mr. Chairman, Senator Kohl, Senator Bingaman, Senator Lieberman, and Senator Heinz, I think that the presence of each of you here today demonstrates the keen interest that you not only have in this subject, but certainly recognition as well of the fact that we are facing a national crises, and a crises that is further upon us than perhaps many people wish to realize.

Mr. Chairman, if I could be given just a moment or two to give an example, an illustration of the material that I want to cover this morning. Back in 1957 we had one of those seasonal recessions in Oregon. The following year I was elected Governor of my State to try to lead the State out of this recession, which was based on an over dependence of a natural resource base of timber production.

I called together, first of all, a group of educators, and we came to the conclusion there were two major gaps in the State's educational program. One was at the community college level—Oregon had only one at the time with a heavy emphasis upon technical education—not just the traditional vocational education, but more than that, a kind of education that would lead to paraprofessional programs and paraprofessional graduates.

Secondly, we found that we were very, very weak in our post-doctoral programs. Even though we had three statewide universities, we were diluting our educational dollar by duplicating and overlapping our programs. So without the kind of revenues necessary in our public treasury, we called upon Oregons industry to invest in the technology necessary to maintain the progress in their industries. We launched a graduate center that celebrated its 25th anniversary last year, the Oregon Graduate Center. And it has been very successful.

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[1] See p. 53

The community college program, with both its transfer and its technological curriculum, gave us the opportunity to expand our technical trainees and the person power pool necessary to meet our efforts to diversify the state's economy. Mr. Chairman, the area of Portland, Oregon today is now the second hottest area, next to Silicon Valley of California, in attracting and in establishing technologically oriented industry. And in part—and I would be less than honest if I claimed the full credit for these educational resources that were developed—but a major part of the success of this diversification effort for the state's economy tracks back to the establishment of those educational institutions.

The crises that I want to share today with you is not an either/or situation. I am proud to be a product of the liberal arts education. I did my undergraduate at a small liberal arts university. I did my graduate program at Stanford University in liberal arts programs, and I taught in the field of political science in the university for 7 years of my life and I am here to say that it is not an either/or crisis.

But I am here to advocate the kind of action we should take to strengthen our math/science program, certainly not at the expense of liberal arts, but as a necessity in so many areas of our national life that we have neglected for far too long.

I happened to live with graduate engineers during my Stanford days in political science, and they were puzzled. My roommate was from Dartmouth. He could not understand why the graduate school of engineering at Stanford required a course in public speaking and a course in political science, because to him as an engineer, it had no relevance. And yet, as school officials explained, in the years ahead you are going into the practice of engineering and you are going to find the big contracts are going to be those issued by counties, cities, States and the Federal Government. You better know a little bit about how the Government functions and you better be a little more articulate than Herbert Hoover was when he graduated in engineering at Stanford University. So consequently, it was a rounding of our education. It was addressing the weakness in our educational program.

Now, I want to stop and move into the noneducational areas. If you talk to Mr. Young today, who heads up Hewlett Packard, one of our great industries in the technical field, he will tell you that over 50 percent of their products today that they sell on the world market have been the result of the last 3 years of R&D. The last 3 years. And the trend is escalating. More and more of our private sector industry is dependent upon R&D coming out of our scientifically trained personnel. And part of our lack of competitiveness today can be tracked back to the lack of personnel in those fields.

Second, let me take the area of medical resources. I see many of these things from my position on the Appropriations Committee. We appropriated about $2 billion for medical research the last few years. In FY 1991, we appropriated about $2 billion for nonmedical research.

Now, in the field of medical research, I can give you an illustration that it is, again, not dollars alone that makes the difference. We have escalated our attention—4 years ago we appropriated $300 million for the research of AIDS. The next year it was $600 million,

the next year it was $900 million. FY 1989 was $1.1 billion and FY 1990 will be $1.6 billion.

Funding is now equal to what we are appropriating for cancer and cardiology, and other diseases in the field of cardiology. In addition, the demands of orphan diseases are great. The need for medical research today is greater than it was 20 years ago plus when I came to the Senate. We find—and the report will be released tomorrow—that instead of estimating 2½ million Americans with Alzheimer's. It will be 4 million under a new analysis, double what we thought in the incidence of Alzheimer's Disease. Today Alzheimer's patient care takes $40 billion out of our GNP. I could go on and on indicating to you that the most productive, highest multiplier dollar that we spend in the Federal Government is in the field of health and health research—1 for 13 back into economy.

And we are not keeping pace. Why? Personnel is one factor. But it is not the dollars alone. We may reach a point where we can appropriate dollars for certain disease research and we cannot get the people to do the research.

We have 11,000 training grants that we established a few years ago in the appropriations process to encourage young medical people to conduct medical research. Last year we had to reduce the 11,000 to 10,000 in order to raise the individual stipend because we are competing for those young scientists with the private sector and all the other sectors that demand this increasing influx of scientists and other people who are willing to do research. That is the medical field.

Now, let me take one other field. One of the Stockholm meetings a few years ago indicated that half the scientists in the world today are involved in military research. We have 100,000 scientists today in and out of Government that are addressing the SDI project alone. Now, you don't have to agree with my view on military spending, to recognize the growing demand for personnel to maintain the pace of military research, not only in our part of the world but other parts of the world.

So, these are three areas that I wanted to raise to your attention which demonstrate the demand side rising.

Now, let's look at the supply side. We have about 25,000 public high schools in this country; 7,000 of them have abandoned teaching physics; 4,000 have abandoned teaching chemistry; 2,000 have abandoned teaching biology; and of those that are still teaching any of those science courses, only a little more than one-third have a laboratory experience.

Our baseline is eroding. It is diminishing at the same time the demand curve is rising. Lets take this one stop further—to me, the most alarming of all. If I had no other statistic to give you today, I would want to give you this one. Fifty percent of those who are now teaching those courses in our secondary school are not certifiable by their own certification agencies. Seventy-five percent of those at the middle school level are not qualified to be certified by their educational certification agencies.

So when you look at the diminishing numbers of schools that are offering the courses, the diminishing opportunities for hands-on laboratory experiences, the diminishing number of those teachers

who are in classrooms supposedly teaching these subjects today, not certifiable to teach the subject, I think it should give us great pause.

We have a demand for 300,000 teachers in our public schools between now and 1995. That is just a little over 5 years from now—300,000. And if we don't get those 300,000 new teachers, qualified to teach those subjects, we will have a shortfall in the labor market in all of the areas of 700,000. We could employ today and for each year between now and 1995, 138,000 degree holders in the field of engineering alone—138,000 per year.

We have been drawing demographically from our white male 22 year old group, the basic supply for these increasing demands. My friends, the white male 22 year old is a flat line in our demographics. And even if we employed more dollars and more dollars, there just aren't enough white 22 year old males from which to draw the needed supply.

So we are going to have to have special programs going out there to attract women, minorities, because now 67 percent of the population at 22 is not white male. The demographics are working against us. Every aspect of this whole problem as you look at it will find a down curve as far as being able to meet the demand increase curve.

About January of last year I started a series of meetings, and I have had 26 now, last year and this year, meeting with national associations in the field of education, elementary, secondary, graduate, research university people. The so-called military/industrial complex. We had a meeting with those who are today producing the instruments for our military that are highly skilled, highly technical industries.

I have met with the directors of the 13 institutes at the NIH, the National Academy of Science, the National Science Foundation, the National Science Advisors, on and on and on. And all of these people will give you basically this kind of picture. It is a national emergency of great proportion, and I feel that, unfortunately, President Reagan gave just the wrong signal when he said to the American people and to the Congress, let's abolish the Department of Education.

Instead of getting positive leadership from the Federal Government, we were getting the most directly opposite kind of leadership, or the lack of leadership. It was not just a lack of leadership, it was undermining the very base upon which we were trying to expand and build. The Congress said no, and fortunately, of course, we maintained the Department of Education. But you can imagine the kind of signal. Senator Glenn and I introduced resolution basically to say: Here is a new signal. Instead of abolishing the Department of Education, saying the Federal Government has no role to play, we are saying this is a national priority.

Now, we are here to follow that signal up with something more significant. Last year Senator Nunn and I introduced an amendment for $10 million add-on to the Defense Department budget for graduate fellowships in engineering and science, 150 3-year fellowships.

My colleagues, I believe, very seriously, one of these days we are going to have to put a surtax on every appropriation bill that uses

research people, a surtax that says as we draw from that person power pool, we have a responsibility to help replenish it. This year the Military Affairs Committee of the Senate made this a permanent $10 million contribution for another 150 3-year graduate programs, fellowships. But we should have it in agriculture, in terms of agricultural research. We should have it in the natural resource bills, in all of the areas that have research involved.

I have two charts that illustrate the competitiveness issue.[1] You see the red bar there on this first one. This is the age 13 competitive or proficiency levels in the sciences showing the United States low in relation to Ireland, Britain, Spain and South Korea. Other nations are lower than we, but it is worldwide, and that is on a scale of zero to 1,000.

The bill that we are now proposing and which we have circulated to our colleagues and to other people to invite their contribution is to establish 9 regional centers in math and technology, consortia in the truest sense. If any of you are in Kalamazoo, Michigan—this is just one example—go to the Upjohn company and let them show you what they have done in drawing out the math/science potential of 12 of the high schools in that county. It is a private industry effort—and they over turn role models. It is a fantastic thing that I have visited, and that would be a part of the consortium, of the private sector, elementary, secondary, higher education centers.

We also feel that we would bring in, in that third point, the Federal support for informal science education. There are a lot of resources out there. The Oregon Museum of Science and Industry. It is a public body. It is a fantastic place to go and watch the exciting things of science. A little girl in Missouri, I think it was, said "Science class is where we go to see how tomorrow happens."

And you know, our tomorrow is a little bit uncertain at this time, but I think there are so many of these independent, noneducational, institutional—educationally speaking—organizations that should be part of this overall consortium. We would provide monies for role models played, for experimentation on how you get the teacher manpower person power pool increased, how you get the student interest. The students leaving our high schools today, within the last 5 years their interest in majoring in science or engineering has dropped 21 percent, almost a quarter of a percent, 25 percent.

So consequently, we have got to do something to reverse that trend as well. We feel that there is a need for a National Clearinghouse for science, mathematics and technology resource materials. We have many agencies of Government that have a part of the action, but there is no coordination. We think the National Science Advisor to the President at the Cabinet level—President Bush has now established that position—should be the coordinator to all of the agencies of the Federal Government involved or having an interest in this field.

All of this means that we could provide resources through the appropriations process—and Chairman Glenn and each one of you appreciate this fully. We cannot just be satisfied with authorizing a

[1] Charts submitted by Senator Hatfield start on p. 118

program—we have authorized a lot of programs—we have got to fund this one. And that is the key role of coordinating this with the Appropriations Committee. Because we have got to get out of the Appropriations Committee, as well as the agencies of Government, as well as the Senate and the House a priority of such significance that, unlike the Homeless Act, unlike a lot of these other things that we have authorized but then not fully funded, Senator Glenn and I and others are very serious about moving this beyond the action of authorizing. We want this funded, because these regional consortiums need not only paper and material and ideas, but the resources necessary to help set up these experimental programs.

It is not going to be one national program. Every region has different characteristics, and we have to address those individual characteristics.

Well, I have taken more time than I intended You have a very distinguished list of witnesses, I greatly appreciate the opportunity to be here this morning and share these thoughts with you.

Chairman GLENN. Thank you Mark, thank you very much.

Does anyone have any questions for Senator Hatfield?

Our first witness this morning is well known to most of us from radio, and television, Dr. Carl Sagan.

Carl, I understand that it would be in order to wish you a happy birthday today. So we start off with that today. Dr. Sagan is from Cornell University and is, a strong advocate for improving science education. I read his article in Parade Magazine a short time ago, and he talked about not only the problem at the university level, but also the importance of science education at the elementary school level.

Carl, we look forward to your testimony.

TESTIMONY OF CARL SAGAN, PH.D., DIRECTOR, LABORATORY FOR PLANETARY STUDIES, CORNELL UNIVERSITY, ITHACA, NY

Dr. SAGAN. Thank you, Senator Glenn. In the interest of time maybe I can put into the record the article to which you referred.[1]

Chairman GLENN. It will be included without objection.

Dr. SAGAN. Let me try to give a brief sense of my approach to this question and try to leave some time for questions.

We are eating the seed corn, and it is well known what happens if you do that. You might get through one more hungry winter, but you are in the deepest trouble the year after.

The idea of saving money by not supporting education is the most astonishingly shortsighted and foolish attitude that it is possible for a nation to have. We are depriving ourselves—in a highly technological, competitive and rapidly changing world—of precisely the resources that are needed in order to accommodate to change.

We live in a world that in many respects is based on science and technology, and at the same time we arrange a society in which hardly anybody understands anything about science and technology. This is a clear prescription for disaster. It doesn't require deep analysis to see that.

[1] See p. 123.

Let me say something about the reasons why better understanding of science and technology is important. I believe it is not just a question of producing more professional scientists and engineers. Certainly there is such a need. But the need runs much deeper. We need much more widespread scientific literacy in the population in general—In part because that is what is necessary to produce professional scientists and engineers, but for other reasons as well.

There are four categories of reasons, it seems to me: One is the absolute bread and butter issues of jobs, profits, the health of the national economy, all of what is sometimes summarized in the phrase "international competitiveness." If furniture companies cannot make furniture because entry level applicants cannot do elementary arithmetic, then furniture companies will close down and the furniture will come from somewhere else. If a leading American electronics manufacturer finds that 80 percent of applicants cannot pass a 5th grade arithmetic test, then the competence of the work in that company, and the quality of the products will decline and jobs will migrate to some other country where they take greater care with science and mathematics education. These are simple bread and butter issues.

American industry recognizes that this is a problem at the present time. Estimates are that something like $25 billion is spent annually by industry on remedial education of their workers and on lost productivity, and my guess is that this is a very low estimate of the cost.

The trouble is that industry generally, especially in this country, is interested in short term profits. And for economic competitiveness, you have to make the investment now to get the benefit 10 or 20 years later. In many American industries the complete board of directors turns over in that period of time. The individual motivations of the executives to do something that will benefit their successors a decade or two hence is not impressively large.

In other countries where it is common to have longer-term planning, it is more common to plan things for ten or twenty years in the future. All this being the case, what is the American institution which, at least in principle, can plan over those longer periods of time? If it is not industry, might it conceivably be Government?

The second reason for much letter science education has to do with a wide range of key, in some cases unprecedented, problem that face the United States, and many other countries as well, in which finding the solution requires understanding science and technology. And that applies to the citizens who must vote for legislators and presidents, and the legislators and the members of the Executive Branch as well.

It is certainly a very long list. It certainly involves all sorts of military activity. Senator Hatfield mentioned SDI. That is an excellent example where elementary understanding of science helps to understand what is practical and what is political hype.

Or let's take issues of the global environment. Here a set of extremely grave problems face the world. Our technology is now so powerful we can alter the environment of the planet. Greenhouse warming is one example. Depletion of the ozone layer and consequent increase of deadly ultraviolet light at the surface of the Earth as a result is another. The solutions are complex. They in-

volve an understanding of the underlying science. It is necessary to be able to make intelligent judgments: are this just a cry of doom and gloom or is it a real looming catastrophe?

How can you make that decision if you don't understand the underlying science and technology. How can the voters decide which representatives to represent them if they, the voters, don't understand the issue? This seems to me an extremely important reason why we have to understand science and technology better: the solutions to such problems are going to involve science and technology in the deepest way.

Likewise, for the apparently emerging era of massive arms reductions, there are important science and technological issues there about how to find a safe path to much smaller arsenals.

There is a third reason which you can find readily enough in first graders, but much more muted in, say, high school seniors—the thrill of understanding the universe, which I believe everybody is born with. I think it is part of being human.

Everyone wants to understand our origins—people, life, the Earth, the Sun, the Galaxy, the Universe. Science has a range of answers and a range of deeper mysteries uncovered in those answers and my experience is that almost everyone is ignited with excitement when presented with those findings. Understanding the world we live in is deeply satisfying. It is the birthright of every citizen. If we don't know anything about science and technology, we are unequipped to that joy in understanding experience.

And then finally, and maybe most important, is the fact that science is not so much a body of knowledge as it is a way of thinking. There is a generally accepted scientific ethos, sometimes not perfectly adhered to because scientists are human beings like everybody else. Nevertheless, it is recognized worldwide throughout the scientific community as at the very least what we should aspire to. It involves the idea that experiments must be verified, that arguments from authority carry zero weight—people in authority have made mistakes before and they will do so again—vigorous substantive debate is healthy; quantitative thinking is an important way of distinguishing the wheat from the chaff. This kind of thinking works, and is responsible for the success of science. But it is not widely used in other areas of human endeavor, particularly in social, economic and political areas.

Too often there is a tendency simply to accept what we are told; only later do we discover that the people in authority did not have the foggiest idea of what they were talking about. There are many examples of this sort readily available, especially from recent presidential politics.

I think that the very existence of a democracy requires a citizenry well versed in substantive argument and in the idea that you carry alternative working hypotheses in your head and see which best matches the facts—not that you uncritically apply a doctrine which has been handed down to you. The world is changing too quickly for that.

Any one of these four items would justify much more thorough and consistant support for science education on all levels. The combination of all four of them I think makes an absolutely compelling case. It is a pity that it is even necessary to have hearings such as

this. The fact that the problem is being urgently addressed now is a rebuke to us for what we have not done in previous years.

What should be done? I would like to stress that the problem must be attacked on many levels at once. It is not just a question of improving elementary school teaching or fellowships for universities or regional centers for the improvement of science competency in high school teachers. All those are certainly necessary, but this has to be done at many different levels simultaneously to address the many different timeframes involved, because we have to worry simultaneously about next year and 10 years from now, and 20 years from now.

Senator Glenn mentioned my article in Parade—Parade has a vast audience, 65 million readers every issue and so I tend to get a lot of mail, not all of which I can answer. But the mail certainly gives a kind of sense of the pulse of the nation, or at least of those concerned enough to write back. There are wide range of opinions.

The most common letter that I got complained about the inadequate training of science teachers in the school system. And worse than that, the unwillingness to answer questions, a kind of rigid doctrinaire nervousness about having their ignorance exposed. That clearly is the very antithesis of what we need to teach science, to encourage science, to make kids comfortable and enthusiastic about science.

We want teachers who are themselves comfortable with science, who understand it, who can answer questions. So surely there must to better teacher training, remedial education for science teachers, making the content rather than the method of teaching important for teacher certification, rewards for competence. If the kids do well on objective national tests, the teachers ought to be rewarded on some level.

There is the question of laboratories. Laboratories are expensive, but if you don't have laboratories in teaching science, then all the kids get is science out of books. Science out of books, if the books are good—many of them aren't—is terrific. But it is very different from understanding how science really works. And many school districts, because laboratories are expensive, have cut back or abandoned laboratories. What results is teaching a kind of distillation of science, a summary of the findings but not the methods of science, not science itself.

Scientists need to be encouraged to spend more time teaching science. There are a large number of scientists who find it extremely vexing even to have to explain what it is that they do in terms that are readily comprehensible—much less spend some portion of their time talking science in the lecture circuit or in school rooms or on television or radio or writing popular articles. There has to be a way—and it need not necessarily involve money, humane or patriotic motives might do it—for getting professional scientists much more heavily involved in the teaching of science on all levels.

There is a very serious problem with the media. The media are the quickest way—especially television, a visual medium—of changing attitudes, of increasing the respectability of intellectual discourse in general, and science in particular. It is remarkable to me that virtually every newspaper in America has a daily astrology column but few have even a weekly science column. That says

something about what we value and hold dear, what we consider important. A visitor from somewhere else just reading our newspapers would get, I think, a very negative view about our seriousness about science and engineering and therefore our prospects for the future.

Astrology—as I know I don't have to say here—is bunk. It is a fraud. It doesn't do what it portends. And yet it is there, in every newspaper, with one or two exceptions, remarkable.

Or consider the world of television. There is a fair amounts of pseudoscience on television, occasional stories on medicine and technology, but almost never anything on science. Science clearly has to be distinguished from medicine and technology. Not threats to our health, not new machines, but understanding the world, new discoveries in figuring out how the world works. We never see that—almost never—on television.

In the whole world of television drama, there is not, as far as I know, a single program in which the hero is someone who is passionate to find out how the world works. There are no role models. It is not surprising that kids don't tumble to science if they have nothing in their everyday lives which encourages them to go in that direction.

And that brings me to my last point, and that has to do with the issue of promotion and salaries. There are statistics which show for the first 8 years after high school most American males get no tangible rewards from competence. If they know how to read and write better than average, if they know how to do elementary arithmetic or algebra better than average, this is in no way reflected in promotions or higher salaries. In part this is due to the fact that so many young people go into service jobs, where it is not required to do too much thinking.

In the productive sector of the economy, of course, the story is very different, and that returns me to what I was saying at the beginning about all the industries that find entry level applicants cannot pass the most elementary tests.

If it were true—I mean, American kids aren't stupid—if it were true that doing well in these subjects make you more money, then I think they would do well in those subjects. And if it doesn't, the way the educational system is now arranged, there is no encouragement for them to do well.

I've tried to give a very brief summary of the situation. It is an extremely important issue. It fits into the generic of short quandary-term versus long-term issues, which are the most serious and the most challenging category of issues we face. I very much hope that the Congress will not only authorize but fund major steps along these lines consistent with the leading role of the states in supporting education.

Thank you.

Chairman GLENN. Thank you very much. You have given us a lot to think about, and we could spend a lot of time of on each one of those particular areas.

We will follow the 5 minute rule this morning.

You mentioned low teacher salaries, antiquated lab equipment, too little homework, and parents unwilling to pay for quality science education. Those exist at the local level. They involve elemen-

tary and secondary schools, which are under the province of the states and the local jurisdictions.

We have had a number of things suggested that we might be able to do at the Federal level. It has been suggested that we set national standards of rating high schools, which would let each community know how their high school measures up. Also, there are proposals for national standards for graduation. We are the only major industrial society that does not have some sort of standard like the French Baccalaureate.

Before you came I mentioned the Ross Perot study. He spent a year studying their system. He found out that 65 percent of the high school principals were coaches. Now, I don't have any problem with coaches. Most of them are very highly qualified academics. But 65 percent may show an over emphasis in a direction that doesn't necessarily have anything to do with excellence in education. Thirty percent went to good solid academics, 30 percent of their money went to soft electives, as he termed it, and 40 percent to extra curricula and administrative functions.

Dr. SAGAN. I know it is in some circles customary to say that you cannot solve problems just by throwing money at them, and that is true. But a lot of problems also cannot be solved unless you throw money at them. Money is not all that is needed, but there is no question that money is needed. Money is a necessity, but not a sufficient condition.

The point about coaches is very interesting. Look at the recognition that, let's say, high school students who have great competence and excellence in sports receive. What comparable recognition is there for high school students who have great excellence and competence in science or engineering or mathematics?

I am talking about notices in the home town newspapers. That is something that Members of Congress can do something about. I am talking about recognitions in assemblies and group activities involving the whole high school. There is an ethos which says that competition and excellence in sports is desired, is encouraged at all levels of the community, whereas competence and excellence in science, let's say, is in some circles—including, often, the students themselves—a cause of embarrassment. In the student culture of the high school, there is pressure not to excel in academics. You will embarrass your fellow students. You will force them to work harder. More will be expected of them. So there's peer pressure for those who are smart to pretend to be dumb, in all areas, except athletics. There is no peer pressure for excellent athletes to pretend that they are not excellent so they won't embarrass their less competent colleagues; we never see any of that.

It seems to me that on issue of what we encourage and what we discourage the Congress of the United States might have some leverage.

Chairman GLENN. Do you think we ought to set standards? Would that work, if we put rating systems out there or required that we have some standard of pass/fail for getting out of high school, as the French Baccalaureate or other systems do?

Dr. SAGAN. It is a tough issue, and let me say why. There is a danger of abuse. And this is, to my understanding, the reason that the framers of the Constitution put education primarily at the local

level. A wise and prudent and far-sighted national commission establishing standards might do an excellent job, but there is a potential for abuse. There is a potential for nationally mandating particular political or religious points of views. If you can walk your way between those two shoals, my hat is off to you.

Chairman GLENN. Perhaps, the courses taught could be a measure. In other words, if a school offers certain courses and qualified people to teach them, that is one threshold to get past. If they did not even come up to that minimal standard, then they obviously aren't qualified. I think you could set up 4 or 5 different gradations along that line of what schools are even offering.

Dr. SAGAN. There I agree with you. You certainly could set standards for teachers which don't run afoul of what I just was talking about. But think about the idea of mandating curricula: there's a bunch of people in Washington who tell people in a small town in Missouri, say, what their kids should learn and what they should not. There is something potentially dangerous about that.

I think the idea is to encourage the highest standards of excellence and people in local communities will eventually understand what it is that their kids should learn.

Chairman GLENN. My time is up, but I think at the Federal level we have taken the lead since World War II in supporting college education—through grants in aid and all sorts of programs you are familiar with—and supporting our young people beyond the high school level. That has been mainly the Federal role.

At the elementary and secondary level I think we got up to around 9 percent. I think we are down around 6.5 percent right now in our support for elementary and secondary. We still look at that as the province of the states and local communities yet. That is where our problem is starting.

Dr. SAGAN. May I just make one response to that?

Chairman GLENN. Certainly.

Dr. SAGAN. A very important thing—it is a long lever arm—but a very important thing the Government can do is support for programs such as Head Start, and programs alleviating perinatal malnutrition. If you are a fetus and your mother doesn't have enough to eat, no matter how good your genes are, you are going to wind up with an intellectually deficit later on. An excellent use of Federal money is to make sure that every infant has enough to eat and to encourage kids to get going on education early, before kindergarten.

Chairman GLENN. Senator Kohl?

Senator KOHL. Dr. Sagan, I would like to pursue this question of the need, the obvious demonstrated need versus the lack of supply.

You said—I think we all understand—that people gravitate in terms of their life pursuit where they can do the best. And you talked about exaltation of sports and things of that sort, that's true. But it is a clearly demonstrated axiom now that we need people in math and science, that that is where excellence is going, that is where vocational opportunities are going. That is where you can be sure, if you are a young person and educate yourself, and prepare yourself, you are going to make a good living and are going to be in demand. You are going to succeed vocationally.

I mean, if we haven't made that point in this country, we certainly are on the way to making that point. Now, given that, then why aren't we seeing the vacuum of science and math illeteracy being filled, or are we just beginning to move in that direction? And are we on the right track?

Dr. SAGAN. In trying to understand this issue I also had to wrestle with that question. It seems so straightforward. If we desperately need competent people then we ought to be rewarding competent people, then kids in high school ought to see that if they learn science and mathematics they will reap those rewards—so they'll do the learning. But the trouble is that there are lots of jobs for kids who graduate high school for which this is not the case, in which you have gone through all that effort to understand the binomial theorem and they don't at all care about it in the serving of hamburgers. It hasn't helped you in the least.

It has to do in part—this is a simplification—to the distinction between the service and the productive parts of the American economy. The service economy doesn't need that kind of stuff, and where are the bulk of the jobs for high school graduates?

Senator KOHL. But these, as has been demonstrated over and over again, these service type jobs are the lower paying jobs, and the jobs we are talking about are the more exalted high paying jobs. Now, if it is just a question of disseminating that information, we can do that. That is not something that cannot be done.

So I am still missing in my own mind the understanding of how we get to where we are going. If it is true in our society—I want to say it again—that the people who are exemplary at math and science are the ones who are going to wind up with good paying jobs versus those service jobs you are talking about, then what's missing? What is missing?

Dr. SAGAN. I think part of what is missing is reliable information provided to the students that what you and I are saying is in fact true. And another thing that is missing has to do with the ethos of the society. Is there a sense of great respect for let's say science teachers, as there was in the 1930's?

Is there a sense of respect towards kids interested in science from their high school peers? Or as I was saying before, is there a social pressure not to excel in science? There are a lot of factors that influence kids, especially in those immediately post-pubescent years when peer pressure is a very important issue.

These are not insoluble problems, but they are not easy either. I think if you talk to anybody who was interested in science in a serious way in most American high schools, except for the ones that specialize in science, you will discover something like this, I can tell you from my own high school days in Rahway, New Jersey, that there were many who were less than delighted that there were a few people who were extremely interested in science. There is a set of strong social factors that have to be worked.

Is it true that better prepared people are the ones who are more rapidly promoted and get swifter salary increases? If that is true, the industries in question ought to be making that clear.

Senator KOHL. You mentioned the problems with respect to the popular media. Yet you have had a large success in your Cosmos

television show. Why do you think we don't have more popular, exciting science programs on TV?

Dr. SAGAN. I wish I knew, Senator Kohl. "Cosmos" was the most widely watched series in the history of American public television at the time it was shown. It has been seen in over 60 countries by more than 300 million people. It has just been released in video cassette by Turner Home Entertainment.

It has done phenomenally well, and it is a demonstration, if one were needed, that you can get real science out to a broad public and have people enjoy it and even ask for more. I am not sure why more of this isn't done. I think it is completely clear that more of this could be done.

Senator KOHL. Thank you, Mr. Chairman.

Chairman GLENN. Thank you. Whatever happened to Mr. Wizard too, at the lower level?

Dr. SAGAN. Yes, absolutely.

Chairman GLENN. Senator Bingaman?

Senator BINGAMAN. Thank you, Mr. Chairman.

Dr. Sagan, let me compliment you on all that you do to make this issue important and prestigious in our society. Your work is very important. I would like to get back to your comments about how we shouldn't have a national curriculum; that there is a lot of valid concerns about that. I agree. But I also think there may be some subjects where we really don't have a valid argument against having national standards, for example, mathematics. I think you cited in your statement that many of our high school graduates are not able to pass a 5th grade mathematics exam.

I am not talking about Congress passing a law saying this is what you need to know in 5th grade math. But why would it be improper to have knowledgeable people from around the country come together and say this is what we in this country would expect the students to know in math when they graduate from 5th grade. And if you are teaching the 5th grade in my home state of New Mexico, or Florida, or New York or wherever, and your students aren't performing at that level, then you would have a very strong signal that your students were below average.

Now, some people say, no, that's a national curriculum. In my mind, it only makes sense. If we are going to criticize students when they graduate from high school for not knowing anything more than 5th grade math, why don't we tell their teachers and their parents and, in fact, the students what we expect of them at each grade and then help them reach those levels of performance?

Dr. SAGAN. I personally have no objection to what you just suggested. It makes perfect sense. There is no serious religion, as far as I know, that has objections to quadratic equations the contention that the Earth is round.

But the trouble is when you get to other areas. What happens when you get to physics? It turns out that there is excellent evidence that the Earth is about 4.5 billion years old, but there are religions that believe it is only 6,000 years old. What happens when you get to biology—when evolution, the central idea of modern biology, is considered anathema by a number of religions? Then what do you do?

Senator BINGAMAN. I understand that you can get into areas that are more controversial, but I think that we do have agreement in some areas and we need to move forward in them.

I agree with all of your suggestions about the long term we need to train more educators; we need to recognize those who are teaching in these areas, who are excelling in these areas.

In the short term, however, while we have a deficit of qualified, certified people teaching in these areas, to what extent can we use modern technology—through video programs and computer programs of various kinds- to fill that gap and ensure that this generation of elementary school students does not miss the chance to become excited about science?

I saw something a few weeks ago indicating that most students who decide to pursue science as a career make that decision by the time they are in the 7th grade, and those that decide not to go into science also make that decision by the 7th grade. So there is a period of time, very early in a student's career, when we need to excite them. If we don't have teachers in the classroom who are capable of exciting them, can we do it through technology?

Dr. SAGAN. Technology is a tool, but everything depends on what the technology is presenting to the student. If it is cold, remote inaccessible, doesn't answer questions—because, you know, much of this technology doesn't answer the student's questions, it is not interactive—then it is not clear that it could help large numbers of students, especially those with science phobia. For those who are already committed to science it is wonderful, because it permits them to go far beyond their grade level. But as for general encouragement, there is nothing better than a live human being who is in front of the students and is genuinely enthusiastic and knowledgeable about the subject.

Nevertheless, I think some things could be done along these lines. Certainly television—the "Cosmos" experience has clearly shown that television can cross that barrier, can get a kind of human contact across, but it has to be designed to play that role.

Senator BINGAMAN. Thank you very much.

Chairman GLENN. Senator Lieberman?

Senator LIEBERMAN. Thank you, Mr. Chairman.

Dr. Sagan, thank you for being here and thank you for all you have done to increase people's awareness of science. If I may bring any personal experience to this, Mr. Chairman, now having begun a second family, as it were, and having a 19th month old, I am reassured to find that Mr. Wizard after all of these years is still growing strong.

Chairman GLENN. I don't think widely enough distributed, though.

Senator LIEBERMAN. The closest scientific hero that American television provides to its watchers in this age I think is McGyver, and that is not too close. In other words, McGyver gets himself out of these adventurous dilemmas he is in usually by some clever use of science or technology, but that is a long way from where we want to be.

Before I ask you a question, I want to see if I am operating on a correct factual or historical basis. I have been reading all the statistics that you cited in your articles, and others have cited, of the

relative weakness of American students and graduates when it comes to science and math and technology compared to other nations. And, of course, all of us here worry about the effect that is having on our international economic competitiveness.

Am I correct in assuming that during earlier times in this century when we were a surging economic power, early in this century, or in the post-war period, that if we had taken similar studies they would have shown our students doing much better as compared to students and graduates on other developed nations?

Dr. SAGAN. Senator Lieberman, I don't know the answer to that, in part because of the studies that I know about, the longest ranging only goes back to the late 1960s or early 1970s. So I cannot tell you about longer baselines.

The National Report Card on Science, which is administered by Educational Testing Service in Princeton does go back to, I've forgotten, but roughly 1970, and the conclusion there is that we are no better or no worse now than we were then.

Senator LIEBERMAN. That would be interesting. I guess the question I wanted to ask, and I will go ahead and ask it anyway, even though it is not clear. But I think when we see these statistics we assume that our country is sliding, that we are going down. And I wanted to ask you—and this takes you somewhat out of your field—but what has changed, compared to when you were growing up in Rahway? What's different? Do you think somebody growing up in Rahway today would have been drawn to the career that you chose? And if not, I wonder why.

Dr. SAGAN. Well——

Senator LIEBERMAN. Or if you were growing up today in Rahway?

Dr. SAGAN. You have invited me to speculate. Let me do so.

The last 10 years seem to me to have been a particular disaster in this respect. In the last 10 years we had an ethos of greed foisted onto the American people; agreed is what you should be interested in, the people were told. The brightest people were encouraged to become, lawyers or commodity brokers or arbitrageurs and not scientists. That is where the rewards were that the society sanctioned from the very top.

In the same period of time there was not a great deal of intellectual rigor or intellectual honesty that one could see emanating from the highest levels of the Government. There were obvious attempts to deceive the people, to lie and hope that no one noticed. Eventually people noticed. If there isn't a deep respect for the truth at the top, that attitude propagates down.

There are many criticisms we could make about, let's say the administration of John Kennedy, but in that administration there was a respect for intellectual achievement that also propagated. People of a variety of different political beliefs encouraged excellent scientists to become deeply involved in the Government. There was a President who actually had dinner with Nobel prize winners, that included substantive discussion, including his remark that "This is the greatest collection of intellectual talent that has been ever assembled in the White House with the possible exception of when Thomas Jefferson dined alone."

Anyway, that is part of my guess as to some of the reasons.

Senator LIEBERMAN. Thank you very much.

Mr. Chairman, may I ask one follow-up question. It is a fascinating answer in so far as it suggest the important role of Government and Government leaders in setting a standard.

What about the role of the family? And I know again I am taking you out of what may be an area of your expertise, but we continue to read that one of the things that is powerful in Japan, for instance, which we always compare ourselves to today, is the pressure from the family to succeed. Is that part of our problem here now, and is that different?

Dr. SAGAN. I think it is, Senator. I think in the Depression in this country many families recognized that scholarship, intellectual attainment, was a way to get out of poverty. I think many immigrant families recognized that. But now that we are economically better off, except for new immigrant families there isn't much pressure on kids. If you look at the recent phenomenal performance of Asian Americans in science and mathematics—and it really is something to behold—part of the reason may be that the language differences are such that it is very hard for them to excel in the literature or social studies or other places where real competence in English language is a prerequisite.

But science and mathematics, being an international languages, are more accessible. It is very clear from talking to excellent students from that background that their parents not just were after them in a negative sense, but in a positive and supportive sense, up with them late at night encouraging them bringing them tea, as one person who just wrote to me said.

The parents need not know the science, they need only understand that it is very important for the success and future of their children and the nation and the world. It can have an enormous influence.

Senator LIEBERMAN. Thank you. Thank you, Mr. Chairman.

Chairman GLENN. Thank you, Senator Lieberman. I wish we had another hour to go just on that last subject alone, because I think young people tend to rise to the level of what is expected of them. And yet we are a mobile society; 20 percent of our people move to a different domicile every year. There are a number of things in that area I think we have to look at also.

We do have to move along. Thank you, Dr. Sagan. We appreciate you being here this morning.

Dr. SAGAN. Thank you, Senator Glenn.

Chairman GLENN. Before we move on to our next witnesses—and we are going to change the order just a little bit here because of some other things—I wanted to point out that I understand we have a group of Soviet high school students that are visiting and are sitting in our hearing this morning in the back of the room.

Would you stand stand up, please.

[Applause.]

Chairman GLENN. Good. We welcome you this morning. Thank you very much, and I am glad you could be us this morning.

VISITING TEACHER. Excuse me, Senator. There are 17 high school students from Moscow. They are on their way to Albuquerque where they will attend high school at La Cueva in Albuquerque, Senator Bingaman's home state.

Chairman GLENN. Good. And I believe Senator Bingaman is going to meet with them later this afternoon.

VISITING TEACHER. And then an American high school group will then go over and study at their school next spring.

Chairman GLENN. It should be very interesting. Good. Thank you all very much.

We are going to change the order here just a little bit. Dr. Rutherford has to be out of here by 11:30. We have been running a little bit late, and also Mr. Aldridge has to catch an airplane, an international flight. He's leaving the country here for a short trip and has to be out. So if our other witnesses don't mind too much here, if they are able to stay, we will have Dr. Rutherford and Mr. Aldridge come up. And we welcome you this morning here and welcome your testimony.

Dr. Rutherford, would you lead off, please.

TESTIMONY OF F. JAMES RUTHERFORD, PH.D., CHIEF EDUCATION OFFICER, DIRECTOR OF PROJECT 2061, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, WASHINGTON, DC

Dr. RUTHERFORD. Thank you, Mr. Chairman. I appreciate being invited here—and Senator Lieberman—to comment on these very important issues. My testimony will be submitted to you so I will not cover all of that.[1]

Chairman GLENN. It will be included in the record in its entirety.

Dr. RUTHERFORD. Thank you. What I would like to do is just take a few minutes to talk about a major effort being undertaken by the scientific community to deal with these very same problems as a way of signaling to you that we in the community look toward the Congress and the Administration to work with us in collaborative ways to achieve these common national purposes.

But I do think I should comment just briefly on the context of this whole business of reform. This is the third time since the end of World War II that the Nation has come to this same point, and we have made these same statements. It was industrialization after World War II. It was the space race in the 1960s. And now we have got international competitiveness and the rest of these things.

You know, during those periods we did lots of things. We trained teachers and we did curriculum over again. We had collaboration with business and industry. We did a lot of good works, but it did not add up to national reform. So when we entered into the proposition back in about 1981 when we became concerned—the American Association for the Advancement of Science—again about these problems, we decided to try and find out what had gone wrong, why hadn't the Nation solved this problem long since. And we came to several conclusions, and I will just mention without explaining and then turn to the other matter.

First of all, is that we haven't treated it as a national problem. It has been treated as sort of a local thing, let the local folks do better, let this state or that state. But this is of national consequence, it is a national emergency. As a consequence we haven't

[1] See p. 61

had a national strategy. We have had no way of thinking about how to go about solving the problem. We do this good thing and that good thing, but imagine that we had tried the build our interstate highway system that way, or get to the moon that way. We wouldn't have achieved it. A lack of national strategy.

Our reform has been by accretion—do this, do that, let's hope that it adds up. Well, it has not added up.

Our efforts have been fragmented, they have been spasmodic. We are on again off again. The fragmented—Congress is that way, isn't it? When it looks at science education, there are all sorts of committees and subcommittees that get interested in it and do things that are of some interest and usually useful, but they come and go and they are not seen as a part of a total thrust to get things into order.

Consequently we have had no coordination within Government, let alone between Federal and state and local activities. I can give just one example. In my judgment, there are several dozen Federal agencies that ought to be active in science education at the elementary and secondary level. We keep mentioning the Department of Education and NSF. Well, NIH and Defense and Labor and Commerce and many others have an interest and are doing little and no one is coordinated.

Another problem there has been all along is that the magnitude of our effort hasn't matched the magnitude of the problem. Now, we are talking about 2 million teachers, a business that spends over $200 billion a year, and yet we imagine we can change it by investing a few millions of dollars, or a few hundreds of millions.

We have a scale problem here that we haven't faced up to in many ways, and the money problem being part of it. It is easy enough to say that, as was pointed out, money won't solve the problems. Without investing in reform we will not get reform. But investing in reform is very different than supporting the status quo, and most of the Federal and state dollars go to operating the system we have now, which isn't working well, instead of going in to transform that system into a new kind of enterprise.

One of our great weaknesses is we haven't had clear national goals. Senator Lieberman, I think you were heading in this direction. If we don't know what we want to achieve, if we don't know clearly what we want our children to know and be able to do, how can we organize our efforts to get there? We have to be clear on these things, and I think there needs to be national expectations because we are a Nation and because, as Senator Glenn has pointed out, our people keep moving.

Finally, let me say that a lot of our solution since World War II has been to load more on to the schools. Every time we defined a problem, we say the schools ought to do something about it. Whether it is bad manners on the highway, or AIDS, or being a good citizen or what have you, let alone the intellectual outcome, when probably what has been needed is a trimming down so that we can focus in on the things that really matter.

Well, with those notions in mind, we designed at AAAS Project 2061, which is an allusion to Comet Haley, which was around when we started in 1985, to sort of give the image that the children born

when we started are going to live to see the return of that comet. The question is, what will the world be like then?

The answer is, it depends on how well we educate those children. They will determine whether we have a habitable world that is worth living in. So we set up this project to be long term. We committed ourselves to 25 years of effort, not on again off again. We committed ourselves to be comprehensive, that our approach would be across all of the sciences and mathematics and technologies simultaneously, not just physics, chemistry and biology, that we would focus on all of the schools, not just the ones who respond well, that we would be concerned about the education of all students. That is, you start with a common core of learning as what we really worry about and build on that. That all grades count, as Mr. Sagan said, kindergarten through the 12th grade, and that we would deal eventually in this period with all components of the system, not just this piece or that piece, hurly burly. But you have got to deal with the curriculum, with materials, with testing, with teacher preparation, with the structure of schooling, with policies and more.

Furthermore, that we would do this by trimming down this overstuffed and undernourished school system of ours, and in the process reexamine all of our premises about learning, about kids, and organization and the rest of it.

The project would be collaborative with every level of education, but the teachers would have a central role, a creative role, and finally that the entire effort would be based on specifying laying out the goals that have to be achieved and that all our work would focus in one way or another on the tests that will contribute to these national goals.

Thanks to the Carnegie and Mellon Foundations, we were able to engage some 350 scientists, engineers, philosophers, historians, educators for over 3 years to do this piece of work, which we think is a central and important contribution. It was headed up by people like Bill Baker, that many of you know, who was chair of Bell Labs, Marvin McVicker from MIT. And the result of that work for 3 years is a statement of goals and some panel reports and then a Statement of Science for All Americans.

One will find in that what amounts to, we believe, the most thorough statement made in this century of what constitutes across science, math and technology, the kinds of knowledge, the level of understandings, the nature of the skills that everyone can and should possess.

We bring that your attention and hope that as you in Congress work to help find solutions that you will also look at it in terms of goals, ours or others, that can be looked upon as what we want to achieve nationally. During this period of 3 years, 4 years, we are working with teachers, panels around the country to define alternative curricula that will reach that. We are going to design the best people in the country we can find to define the specifications for testing, materials, construction, that will contribute to the new curriculum which will lead to the new goals.

So as we do that we will try and keep you informed to the degree that you interested in this. I would say that in the work we are doing now, not only have the foundations, such as Carnegie and

Mellon and MacArthur responded, but the National Science Foundation is providing support, business and industry, IBM is providing a complete electronic network for our people, and the participating state apparatus are participating also.

So I bring this to your attention just as one example of what the scientific community can do to try and move us toward thinking long term solutions, a systems approach rather than a helter skelter approach, and one that is fully collaborative between the scientific communities, the educational communities, and policy makers such as yourself.

Thank you very much.

Chairman GLENN. Thank you very much.

Mr. Aldridge, Executive Director of the National Science Teachers Association, your testimony, please.

TESTIMONY OF BILL G. ALDRIDGE, EXECUTIVE DIRECTOR, NATIONAL SCIENCE TEACHERS ASSOCIATION, WASHINGTON, DC

Mr. ALDRIDGE. Mr. Chairman and members of the Committee, thank you for inviting me here today. I would like to briefly comment on a few of the issues that were raised today and to make a few comments about the testimony, but would like the written testimony to be entered into the record.[1]

Chairman GLENN. Your entire statement will be included in the record.

Mr. ALDRIDGE. Thank you. I must say I am reminded by Carl Sagan's presence here today of the fact that this Nation employs 30,000 astrologers but only 3,000 astronomers. Perhaps that is a reflection of some of our difficulties. I might add that we produce more prisoners from our schools than we do scientists. That is perhaps a reflection of a problem in this Nation.

Mr. Chairman, you mentioned twice Mr. Wizard. Don Herbert is a good friend of mine. I spend a lot of time with him. He is actually on 130 commercial television stations right now, and he also is on Nickelodeon. My own grandson watches those programs, and I'm sure a lot of other children do, so as well. There are people doing something besides Carl Sagan in this regard.

I am going to try to just skip around and look at a couple of topics there were raised, because they are terribly important. One had to do with the fear of the Federal Government instituting some sort of a national curriculum. Let me point out that there already is a national curriculum. It is the one produced by the publishers. Forty percent of the textbooks in secondary school science today are sold by two publishers. Those two publishers essentially determine the national curriculum.

There are ways that the Congress can encourage national efforts without making it a Federal curriculum. There is a difference between a national curriculum and a Federal curriculum. The National Council of Teachers of Mathematics and the National Science Teachers Association both, working with large groups of teachers and administrators and others throughout the land, have created standards and frameworks for reform in mathematics and

[1] See p. 73.

science education. Those efforts are presently being supported by both the Department of Education and the National Science Foundation, and they can be enhanced enormously by the bill which you are proposing.

Let me just describe quickly the curricular framework that NSTA has introduced. We have, through support from the Department of Education and the National Science Foundation, a program—a national program, not a Federal program—whereby science will be provided for all children from grade 7 to 12. In essence what we are doing is spreading out the various subjects over 6 years and then not allowing for children to opt out. Keep them in the system! We are convinced that when you reach the grade 11 or 12, the makeup of the group of very talented young people will be more nearly an equal number of young men and young women, and will be a better representation of the historically underrepresented minorities. We are convinced of that and we have some wonderful opportunities to test that hypothesis in schools in Houston and in the State of California and in several other states where we are beginning this process.

But that research and development effort, which in some cases is building upon the goals that Jim Rutherford has provided us through his project, cannot go anywhere without widespread implementation. And that is disruptive and requires the regional consortia and the National Clearinghouse that you are proposing.

If we don't have that kind of support later, what we are doing now is wasted. And it isn't just our projects, there are many others.

Just a couple of other comments. I wish I could have commented before the young people from the Soviet Union left. That is where I am going this afternoon. I am going to Moscow to conclude some negotiations with the USSR Academy of Sciences on a new student publication. This publication is designed to provide the enrichment in grades 11 and 12 for these very bright kids. It is a new magazine called Quantum.

That magazine is coming out in about 3 weeks. We have asked the President of the United States to deliver the first copy of the first issue to President Gorbachev on December 2nd. And his people in the Soviet Union will be asking the same thing.

This magazine, through the assistance of scientists, leading scientists and mathematicians in the United States and in the Soviet Union, is the kind of cooperative effort that we want to try to increase between these two countries. We see that kind of cooperation as the mechanism by which we are going to reduce expenditures for defense in both countries so that we will have the money to do what we need to do in education. Because that is where the bulk of the funds are going now, to protect us from a problem that we need to eliminate.

Again, let me stress the importance of the bill that you have proposed, Senator Glenn. The regional consortia, in our judgment, would provide the necessary opportunity for local schools to implement new reforms, whether they are ours or someone else's. It gives the opportunity for teacher training, it gives the opportunity for additional research, assessments and all of the other components that are needed.

It is that initial implementation effort and the retraining of the teachers to allow them to make those kinds of changes that your bill properly addresses. The National Clearinghouse is excellent, and the idea is superb. I've made a comment in my written testimony I want to emphasize here as well. It is important that the materials collected not just be film and written material, but there should be a very strong high technology component. That is, it should be a database and a resource where data and information is communicated electronically. We need to move into the same realm as we find in defense and in the private sector, and that component is very important, and we could talk more about that at some other time.

I don't want to take longer now. I think the written testimony expressed our position, and I want to thank you for the opportunity of coming today.

Chairman GLENN. Thank you very much, Mr. Aldridge. We appreciate that very much.

Dr. Rutherford, what is the target date for completing the Project 2061?

Dr. RUTHERFORD. Well, we hope by 1991 to have this next generation of resources, that is the curriculum alternatives and the other guidelines, and that then we would go to work over the 10 to 15 following years with states and school districts to introduce radical change. So for us it is a process. It is not as though we are going to deliver a change at some time. We are using this whole first period of getting ready rather than doing things in the schools, of lining up resources, intellectual and financial and otherwise, then for a 10 to 15 year campaign.

Chairman GLENN. How does our educational system compare with foreign educational systems? We apparently put more money per student into education than almost any nation in the world. Do we try and take on too many other things, like extracurricular activities? Do they leave things like that to other organizations or to family and community groups?

What is the difference and why do they come out better than we do with when we actually spend more money?

Dr. RUTHERFORD. Well, in the first place, getting better test scores is not the same thing as being better educated. We don't know that. For example, Dr. Miller, who has done testing here on scientific literacy in this country, has had some of his surveys duplicated in Great Britain, and in Britain they did about the same, a little worse than we did. There are some problems in the Soviet Union now about when you can actually test for what people know.

I think our greatest argument is not how we compare with other people, it is just patently evident that by our own standards and for our own needs we are not producing people well educated in science and mathematics.

Mr. ALDRIDGE. Senator, I believe that the problem we have in science and math—in this country particularly in science—is the layer cake curriculum. We are the only country in the world that expects a person to learn all of physics in one year. Everyone else spreads it out over several years. That's built into our framework, a change in that direction.

Imagine learning to play baseball in one year. You are going to go and you are going to develop all of your skills and at the end of that one year you stop, or learning to play the piano in one year. These are low level skills compared to physics. One has to develop over time these different abilities, and that is a problem.

I would point out some contrary achievement evidence, if you will. Remember that recently when we had the Physics Olympiads, the international competition in physics, the top student with the top gold medal was from the United States. And there is a case where by providing the stimulation to the very bright kids, as they have done in the American Association of Physics Teachers, we have been able to do something for that group.

Chairman GLENN. Yes, but I don't see how we can ignore test scores, because giving kids particular problems to solve indicates at least some degree of the mastery of the subject. You can't ignore those completely. And we are failing so far behind that we just cannot ignore those, can we?

Dr. RUTHERFORD. Well, the results are embarrassing, at the very least, when we do so poorly. I don't want to put down the tests, but I am just saying that one has to be careful about inferring from test scores about how well other cultures are doing, because these things are so closely tied. Surely we should be doing better on the tests, particularly the good ones. There are an array of those kinds of examinations, some of which, if you look at them carefully, are not terribly impressive, they reward memory.

A lot of the countries around the world—we did a study of five countries, and we found a lot of countries really press rote memory, which pays off in examinations. But when you get into the kinds of exams that do more than that, the results are a little less clear. But I don't argue that the Japanese and the West Germans in particular do better on almost any kind of an examination than we do.

Chairman GLENN. Do you favor something like the French Baccalaureate before we give kids a high school diploma?

Mr. ALDRIDGE. Senator, my project has a national assessment component. We are going to produce tests that will be used nationally. These tests are going to test performance, measure the ability to solve problems, and have very few objective items of the kind that we find in the typical test.

I served on the board for the international assessment, so I am very familiar with those items, the tests and the way those were administered. I also know the outcomes and I recognize that we came out deficient. There are lots of explanations and reasons. The major reason is that we are weak is because we don't offer the appropriate curriculum. Not enough children study science—if you don't study it you cannot answer the questions—and several things like that.

Dr. RUTHERFORD. I am not terribly enthusiastic, a little ambivalent, but not enthusiastic about student examinations. But I would examine every school and every state on performance against total outcomes. In other words, if a school or a district or a state is not producing graduates that add up, that meet national standards, then I think we ought to know that. But you don't have to test all the students to do that. You can do representative—

Chairman GLENN. Should we have national standards?

Dr. RUTHERFORD. Absolutely. And we are far beyond the place where you can believe that every village in America will come up with the high standards. We have hardly moved in standards from the time when President Conant of Harvard went across the country in 1960 and visited the high schools and discovered that they did have a standard curriculum, the same in every school in the land, and that the standards were dismal. So rhetoric aside, I think the Nation has to decide what it wants its schools and children to be able to do.

Mr. ALDRIDGE. You can have national standards without having Federal standards.

Chairman GLENN. You made that point earlier and I picked up on that. It is a fine line. If you are on a local school board, you are going to probably refer to it as that Federal standard that came down here.

But at least we could start out by making certain that at least schools give a math course up to a certain level, and a physics course, and any chemistry course.

Dr. RUTHERFORD. There could be standards for teachers. There is no reason why we can't do that on a national basis.

Chairman GLENN. You think we could set standards right here and say, you cannot teach a math course in a high school in the United States of America unless you pass X test. You would set that as a national requirement?

Dr. RUTHERFORD. No, but I think one could start off by setting a standard of what would constitute a prepared teacher, and then each year say, this state and this state and this state and this district are falling below national standards.

Chairman GLENN. Okay. That's different.

Dr. RUTHERFORD. Let me comment on the teacher education, if I may. Two million of them out there, and every time you talk about trying the reeducate them, add up the dollars, you are talking about multiples of billions of dollars. I argue we need another method for the reeducation of our existing teaching staff, and that is why we need to redesign the school system instead of just believing we can do some summer workshops.

Chairman GLENN. Senator Roth?

Senator ROTH. Mr. Chairman, I am sorry I am late, and I am going to have to leave because of an appointment, however I do think these hearings are critically important.

Let me just make a couple of comments. I had a couple of science teachers from Delaware visit my office a few days ago. They were in town to receive the Presidential awards for Excellence in Math/Science Instruction along with teachers from each of the 50 states. In speaking to them, I thought their comments were quite interesting.

My concern, after listening to them, is that we continue to talk and study and plan, but I gather, at least from these two individuals, that they don't see much happening. And that worries me very much. The Chairman has a legislative proposal which may be very significant in helping, I haven't had a chance to study it yet.

Chairman GLENN. You will love it.

Senator ROTH. I am sure I will. But I am concerned that we have spent more money, we created a Department of Education, which I was very active in developing with Senator Ribicoff when he was chairman of this Committee. And yet we have not seen any results. Let me start out by saying I am strongly opposed to Washington dictating curiculum. I think that that could be a disaster. In fact, after we created the Department of Education, the first requirement that they laid down was that we had to teach a second language if there were more than a certain number of students, and it wasn't until after a bipartisan group of us—Sam Nunn and myself in particular—that we reversed that. So I don't think taking it to Washington is the answer.

But what worries me is that we create more and more bureaucracy and we pour in more funds but it never gets to those we are really trying to help. How do we he overcome this?

Dr. RUTHERFORD. Well, I don't know. Some kinds of help are going out. For example, the Energy Department national laboratories are providing training opportunities for high school teachers in science. The National Science Foundation is developing some new curricula and has some training.

I think part of it, Senator, is that the scale of investment is so low that it reaches too few people. I mean, what is it that these teachers are expecting to have come their way, might be another way of putting it, that could be provided for them? And the states——

Senator ROTH. Let me ask you, what do you mean by scale of investment? Isn't it true that we are spending more money per student than most countries?

Dr. RUTHERFORD. Yes, but I don't understand the economics of that or how the numbers were arrived at. But if we are spending something like—the figure I saw was $5,200 a year per student—compare that to what it takes to educate a college student, which is easier. That runs $12,000 to $14,000 a year, and daycare runs of the order in America of $4,000 or $5,000 a year. So we may be spending more than some other people, but those are not——

Senator ROTH. But they are getting results.

Mr. ALDRIDGE. Mr. Roth, it cost us $24,000 a year to keep people in prison and we spend $4,000 a year on education.

Senator ROTH. Let me say, I know we can make these comparisons. Let's face the fact there aren't tremendous sums of money available right now.

Mr. ALDRIDGE. Right. Let me point out that some of your more conservative colleagues in years past, in the last 9 years, systematically made sure that we didn't do any kind of national curriculum implementation effort. As a consequence of that, reforms and curricula that came out of the National Science Foundation died because they couldn't be implemented. The bill that is being proposed here reverses for the first time that I know of that trend. We would now permit implementation of national or large scale efforts on a local level where the decisions are made locally or regionally, but still they are national efforts.

When NSF puts $30 million in a project where everyone in this country is involved who is concerned about it in developing those

materials or methodology, it ought to be implemented, not die. That is what has happened in the last 9 or 10 years and that's——

Senator ROTH. Are you saying we should mandate it then from Washington?

Mr. ALDRIDGE. Providing the necessary resources is not mandating. You are simply making it possible for it to be done by the people who know how to do it and who have control over it at the local and state levels. And it is this kind of national leadership that we need, not the sort of thing where we prevent—systematically prevent things like this from occurring. And this did in fact happen.

Dr. RUTHERFORD. For example, under the Eisenhower Administration it became possible to get local funds to put in scientific laboratories in high schools. The schools weren't required to put in labs, but if they wanted to put in a lab or update it, the monies were provided by the Federal Government. So it wasn't coercion, but it was support. Incidentally, that was the last time that we built new high school laboratories in America.

Senator ROTH. Well, unfortunately I have to leave, Mr. Chairman, but I think no area is more important than what we are talking about today and I appreciate you gentlemen being here.

Chairman GLENN. Thank you very much. We obviously could go on for hours with each panelist here this morning, and we thank you. We may want to submit additional questions to you, as other people have, and good luck on your mission to Moscow here. We wish you well.

Our last panel this morning is Dr. Philip Uri Treisman. Professor of Mathematics, Director of the Dana Center for Innovation in Mathematics and Science Education at Berkeley; and Betty Vetter, Executive Director, Commission on Professionals in Science and Technology of Washington, D.C.

Dr. Treisman was recently recognized by Newsweek magazine as one of our real innovators in American education. His math workshops have an extraordinary record in helping minority students learn calculus. They have been replicated in over 25 campuses.

I was very interested in that because I guess my thought was, Dr. Treisman, where were you when I needed you? I got through calculus all right, but I struggled a little bit with it. I could have used your help.

Our other panelist this morning, Dr. Shirley Malcom of the American Association for the Advancement of Science. Dr. Malcom is a well regarded educator and expert on minority education problems.

And I should say about Ms. Vetter of the Commission on Professionals in Science and Technology, she is an authority on human resources issues, and particularly the underrepresentation of women and minorities in the scientific pipeline as well as future demographic trends.

So we welcome you this morning, and Dr. Treisman, if you will lead off we would appreciate it.

TESTIMONY OF PHILIP URI TREISMAN, PH.D., PROFESSOR OF MATHEMATICS, DIRECTOR, DANA CENTER FOR INNOVATION IN MATHEMATICS AND SCIENCE EDUCATION, UNIVERSITY OF CALIFORNIA AT BERKELEY

Dr. TREISMAN. I appreciate the opportunity to speak with you about the difficult problems that we face as a nation in improving math and science education.

I think it is clear from what has been said already—and if I can speak as a teacher—that everyone has done their homework. The problem is quite clear. Although it is true, as a popular back rap song says, that "Denial ain't just another river in Egypt."

It runs deep. But I think that in my work in the university community in the mathematics community, and in the community of teachers, everybody understands that this is no longer a question of national pride or social justice, but fundamentally a question of national survival.

Because there are distinguished panelists here who know the demographics and know the dimensions of the problem, I would like to just speak as a teacher who works on these problems every day. What are the issues that I have to address as a mathematician and math teacher in trying to develop mathematically and scientifically literate students, especially minority students?

The first thing, that was very hard to learn, was that most people working on this problem, especially of producing mathematically literate minority students and scientifically literal minority students, are working on the wrong problems. There are deeply seated beliefs that the problems—when I go out to schools and look around, when I go to other campuses and look at other classes, you see that people believe the problems are motivation. People believe the problems are poor preparation at the level that precedes theirs. People believe that families are a problem, and some reference was made to that today. People believe that income is the issue, that the poor performance of minorities is an artifact of their higher levels of poverty.

But when in fact you actually go out and look, which I did, spending 18 months setting up cots in the dorm rooms of my freshmen, going to their parties, trying to sit with them, put them to bed, actually, and see how they did mathematics and science, you quickly come to see that society's views of what the issues are not real, at least from the point of view of the teacher.

Motivation is trivial. It is easy to motivate students to learn how their bodies work, how the universe works. The students who make it through high school and into college often pay a very heavy price to do so. The students who make it into graduate school have paid an enormous price, yet at each level the presumption is that motivation is an issue.

Prior academic preparation. Someone mentioned that decisions about science are made by the 7th grade. That is true, but it is really a condemnation of the schools. In fact, when you look at who does well, academic preparation is not clearly a factor at all even in college. When we looked at Berkeley students over 20 years, and MIT and Stanford students, we found that in fact the students who were compelling, among black students in particular, and students

of Mexican descent, were not the students with the strongest levels of preparation. In fact, there were marked negative correlations. So our presumptions about the difficulty were not right.

It wasn't just the fault of the schools, the high schools, who blamed the middle schools, who blamed the elementary schools, who blamed the parents, and then someone's mother-in-law blaming the person for marrying that character. It was much more complex.

In my studies of the families of students we had beliefs that the families were not supportive, but we found when we went out many, many mothers with heavy kitchen implements, pointing out their children were going to do well in school. And I have been told by a relative who is an encyclopedia salesman that minority communities are the easiest mark for encyclopedias. The idea that families don't care about their children are at the source of the problem is sort of genetically impossible. The species doesn't work that way.

Income doesn't correlate. I will mention, if you look at black performance, income correlates negatively, principally because so many black children who make it in higher education have parents from one profession—public school employees, which is why their incomes correlate negatively.

So we also saw that there were large numbers of students, the idea of families being the problem. If you look at the schools that produce my best students, minority students, Garfield in LA, Jaime Escalante, 27 percent of all the Hispanics in the United States who passed the advanced placement in calculus exam last year come from this one high school.

Chairman GLENN. Say that again.

Dr. TREISMAN. Twenty-seven percent of all the Hispanic students in the United States who passed the college board's advance placement calculus exam came from one high school. Was it families that created—family support that created that school? No. But I will tell you that family support followed the work of that school and those teachers. As soon as good things were happening in that school enormous parental and community support emerged. And are those students good? He has 200, 250 students taking calculus every year, low income, lower middle class Hispanics. Yes, 50 of them are pretty mediocre from my perspective at the university; 120 of them are really good; maybe 28 of them are fantastic, they could go to Stanford.

Chairman GLENN. Was the movie pretty accurate on how he treats them?

Dr. TREISMAN. The movie was quite accurate. I have had 65 of his students up through 2 years ago. And then every year he produces one or two students of awesome brilliance. Rose Escoval, Roger Para this year, absolutely first rate students who I hope will replace me when I retire at Berkeley. So it shows what the potential actually is.

And when you look at the solutions, what ultimately are they from the point of view of a teacher? For us, we had to think—we had to realize that this issue of developing science-ready and talented minority students and mathematically talented students was being treated as an administrative issue and as a political issue,

and that institutions had developed complex bureaucracies separate from real education to deal with these students.

Moreover, in schools that started improving the performance of students in certain courses, like algebra, it was quickly clear, Stockton doubled the number of minority students excelling in algebra. What happened? Not enough teachers. All right. Double the load moving through any important point and the system collapses because the teachers are gone.

Where are the successes? The Garfields, Berkeley now producing a significant number of minority students, Soledad in Saint Louis, Clara Barton in Brooklyn. In every case it is a group of mathematically and scientifically strong teachers who work in concert with a reasonable administration. And the focus is on solid mathematics and science. Building community around the school, mimicking what I learned about the success of my Asian students. Integration of an intellectual life with a social life, formed around schools.

Is it hard to do? You have seen increasing numbers of schools producing these kinds of communities. Perhaps four, certainly fewer than six, high schools producing half the successful black AP test takers. What are they? Poor, lower middle class schools with teachers who are mathematically trained, who love their disciplines, perhaps recently divorced so they have time on their hands, but working hard with kids.

Now, I think what is clear and what most of these teachers have learned and that we have learned is that these problems have to be treated as educational problems, and one of the difficulties is that these students are being taught a curriculum which is essentially irrelevant.

Bill Aldridge said it quite beautifully, the pancake approach. Students now are learning in high schools the same math curriculum that George Washington would have taken had he gone to high school. Students come out of American high schools without learning a single idea conceived in the last 100 years, a single idea learned in the last 100 years. The time has come to really look at this as an educational problem.

Preparation of teachers is going to be essential. The average age of teachers teaching calculus, chemistry and physics in high school is the over 50, AP courses. As we age average energy—not everyone, energy—average energy goes down. We have very few college students interested in becoming teachers. Fifteen out of the 3,500 Berkeley freshman as one of their top five choices expressed a possible interest in becoming a public school teacher.

We need to construct strong national messages from every sector, professional societies and Government, valuing teaching. I think the religious sector also. There is a slogan of my people that says, "Those who choose to teach the young stand at the right hand of God," and I think that has to be really put out there clearly.

Enormous amount has to be done to strengthen communities, to strengthen families, to strengthen school administrations. But if there are no teachers there, nothing is going to happen. In the professional communities I think we do need to think about national—not Federal—national standards. We need to figure out ways of supporting the scientific community, the AAAS, the National Science Foundation in exactly the way that you propose in your legis-

lation, to make it possible for us—mathematicians and scientists—to work on this problem.

The Federal Government created the research university with its funding policies. Now it needs to figure out in what ways it can help to change the professional definition of the research and faculty communities to make it possible then to work on these questions. Thank you.

Chairman GLENN. Thank you very much. Ms. Vetter, Executive Director, Commission on Professionals in Science and Technology.

TESTIMONY OF BETTY M. VETTER, EXECUTIVE DIRECTOR, COMMISSION ON PROFESSIONALS IN SCIENCE AND TECHNOLOGY, WASHINGTON, DC [1]

Ms. VETTER. Thank you for the chance to talk to you this morning about some of the ways that we need to go about recruiting and retaining women and the minorities, and I am going to stick with women because we have got two minority specialists here.

You are already very familiar with the depressing statistics about the performance of American youth, and especially girls and minorities, on both the national assessments in math and science, and in the international competition with children from other nations. You are also aware of the need to recruit some individuals out of that 66 percent of the population that is not white and male if we ever have any hope of having enough scientists and engineers in this country.

But what I would like to stress this morning is what it would take to have a little leadership that would do something about the devastating effect on achieving our objective that is wrought by our societal mythologies about girls and boys and minorities of both sexes. The pervasive attitudes about the superiority of white boys in math or in mechanical or spatial concepts over either girls or minority boys, except, of course, Asian boys, assure that neither girls nor minorities will generally make the effort to do so well in these things.

Of course, since we have convinced ourselves that the Asian youngsters in our midst are inherently superior in science and math, then most of the non-Asian youngsters, including many white American boys also, drop out of the competition because we also teach our boys that it is shameful if not dishonorable to be beaten by unworthy opponents like girls, or even Asians.

So the number and proportion of American boys planning to enter these fields has dropped steadily ever since we let girls in, and since Asian immigrants increased in the 1980s.

The accomplishment of the Asian students, incidentally, and particularly the immigrant Asian youngsters at the precollege level over the past few years, gives us an excellent demonstration of exactly what I am talking about. What happens when everybody assumes that because you are a member of a particular group—in this case Asian—you are particularly good at something such as mathematics. And, of course, the mythology tells you this. Everything that comes up tells you over and over again how good you

[1] See p. 87 for Ms. Vetter's prepared statement.

are at this because, of course, you are Asian and all Asians do math.

Of course, the opposite also is true. If you are told often enough that girls aren't very good at math, or, "Oh, that's okay, honey, you don't have to do this, I couldn't do math either", or that black children aren't as smart as white children, then the individual will give up when something is difficult or not understood.

And the conclusion of all this is that it is not just our children that need to be educated, it is our whole society. It also shows us how valuable it might be if we could provide our girls with enough self esteem and confidence about their abilities that not only would they not drop out of math and science as soon as possible, but many of them would be persuaded to enter science and math fields, particularly if they understood that the Nation needs them. They don't understand that because it is never told to them.

We know both from research at the University of Minnesota—most recently in a program for gifted mathematics precollege students known as UMDTYMD—and from several other studies, that girls who are mathematically talented are much less likely than similarly talented boys to be selected by their teachers or by their schools for special programs for the mathematically talented, or even to be recognized by their families as being exceptional and provided with a supportive home base.

Girls who do well in math are assumed by their parents to have worked very hard. Boys who do well are assumed to be very talented. When found qualified, the girls were more likely than the boys to reject admission to any special program for the mathematically gifted children. And of course once in such a program, given equal ability and equal grades, the girls were less likely to persist. The lack of appropriate support, either from school or especially from the family, as well as lack of other girls in the class, are all important issues. But it is also important that the message of society to girls is that boys won't like them if they are smart. That is what we tell them now. Girls aren't supposed to be smart, they are supposed to be pretty.

Your proposal for scholarships, one each to a girl and a boy in every State, would do a tremendous amount to say in a very direct way, girls can do science and math. We have extensive evidence to show that differences in capability and talent and personality are much greater between individuals of the same sex than are the generalized differences between the sexes. But teachers and parents and society in general continue to assume that little girls, in comparison with little boys, are better at reading, not so good at math, less naturally aggressive, more interested in nurturing, and so on ad nauseam.

The assumptions are damaging to both the girls and the boys. The teachers continue to treat girls and boys differently, even those who would swear they didn't. They call on girls less often, pay less attention to their answers when they have been called on. They provide less praise for their ideas, and they cut them off or allow the boys to interrupt them before they complete their statements.

These well documented differences continue in college and into the world of work. There has been no national effort of any kind to

try to encourage girls to prepare for science and engineering careers. There have been a lot of programs aimed at minorities, which are good and should be continued. The one program that was set up many years ago in the National Science Foundation to support one-day workshops to encourage women to come into science and math were stopped a decade ago. So were the programs for reentry women, to take women who had a bachelor's degree in one of the science or engineering fields, science particularly, and retread them, get them ready to come back into the world of work.

Today's young women are not encouraged to consider careers in science or engineering. They have never been told they are capable of being excellent in science and math, or that they are needed. And the perhaps equally important piece is they don't even understand the importance of math and nobody thinks to tell them. Boys do understand why it is important to go on in math. They are not quite sure all the time, but they get the good message that it is important. Girls never get the message.

We are now producing fewer baccalaureates in the natural sciences and in engineering every year, starting with 1986 as the peak. We will drop now numerically. In engineering, for example, we are dropping about 14,000 degrees a year at the baccalaureate level, and we will continue to do that for several more years, but women are not only decreasing numerically, they are now starting to decrease proportionally, and they never began to reach parity with the men in this area.

Both men and women freshman indicate a declining interest in majoring in the natural science or engineering fields, and at the higher degree levels which are required for professional positions in the sciences, women earn only 1 out of 5 of the Ph.Ds in these fields. While their percentage of doctoral awards is continuing to rise, very slowly, that is due as much to the reduction in numbers of American men as it is to the increase in the numbers of American women.

There are a number of excellent programs scattered through the Nation's schools that have started in the past few years to improve science and math education, and you just heard about a couple of the more far out and long term ones that I hope ultimately will be widely available. But the problem is to locate the small, healthy trees in this great vast forest of mediocrity, and then to make sure that the root-stocks are available for transplant into other school systems that are ready for the change.

The National Science Foundation, which has funded several of the pilot efforts, ought to be perhaps responsible for determining which ones have been proved effective and should be made available, but certainly the clearinghouse that your bill proposes is very vital wherever that clearinghouse is located.

Several States are moving ahead, both separately and in groups, to institute new educational programs and policies at the precollege level. Many professional groups—and you have heard from some this morning—are working on new curriculum concepts. Industry is providing more and more support to individual schools, and to individual school programs. All these activities are needed and they must continue.

There are very few programs that are designed for women. One of these is the Math/Science Network, which got started at Mills College about 15 years ago. It now reaches about 75,000 girls a year. That is great. It is nationwide; but 75,000 girls is just a drop in the bucket. It should be available to every girl, but it isn't because they don't have enough money. The University of Minnesota's program, known by its acronym, UMPTYMP, has obtained 3 year funding from the Bush Foundation for an intervention program to solve some of the problems in the participation of mathematically talented girls, and to select them. But the problems that have been found in Minnesota for that program are not unique to Minnesota. They are everywhere.

To reach the important goal of increasing our output of scientists, we need more women out of the shrinking baccalaureate population to go on into graduate school and to continue their graduate study, but they are going to need some additional assistance that isn't now available. Women science graduate students now are presently less likely than men, including foreign men in the same field, to have either institutional or Federal support during their graduate studies. They are more likely than men to be self-supporting or to have to borrow money to get through. National fellowships to support graduate students have declined very sharply over the past decade, and instead, funds for hiring research assistants have gone to academic researchers, who are mostly men.

Typically, the male faculty who get most of the research grants—because there are so few female faculty in these fields—prefer to use male graduate students to help with their research, or preferably even male foreign students. So research assistantships, which provide an apprenticeship to researchers working on their Ph.Ds, are just generally not as available to women as to men.

Women graduate students are more likely to have institutional support, which is usually in the form of a teaching assistantship and, unlike a research assistantship, requires extra time from the graduate research program to prepare teaching materials, and in some cases, to grade papers.

It should be noted that although the cost of a graduate education in the same institution is the same for men and women, the ability to repay education loans is affected by the fact that women are paid less than men once they enter the work force. Among full time workers, women earn less than men with the same degrees and experience level in every field of science, and the difference increases with years of experience.

Women have one additional need which results from the fact that their best years for graduate study and for the early professional years and the best years for childbearing coincide. While child care should be a joint responsibility for parents, the reality is that women with small children need additional monetary support to cover child care expenses while they complete graduate work and do their early years on a post-doctoral level.

The lack of funds for child care may require even the best women graduate students to withdraw from a graduate program. Beginning next year the National Science Foundation has just designated 80 of its 1,000 graduate fellowships as a set-aside for women in engineering. That's great, but there aren't enough

women in engineering to take them yet. It is too bad they don't allow some of the fellowships to go to women in the physical sciences, where we need them just as much. It is a step in the right direction, but it is not enough.

While the role of the Federal Government in precollege education is limited, I think it is also a vital one. Some of the legislation of the past, if fully implemented, could go a long way to take care of some of the problems of recruiting minority children and girls in science. Even small amounts of educational difference make a significant difference in the outcome. If intervention doesn't occur here, doing it later is too late.

Head Start, for example, is a proven program which compensates in many ways for the lack of enrichment that is suffered by many children prior to entering kindergarten, but in 1988 only one out of five eligible children was served by Head Start. There was no money.

Education, including intervention education, pays. It is the alternatives that are so costly. Tomorrow's college age population from which we are going to have to draw tomorrow's scientists and engineers, is going to continue to contract through the mid-1990s. This provides a window of opportunity for young men and women which apparently is not yet visible to many of them.

It also provides a real challenge to the Nation. America's talent pool includes equal numbers of males and females, and they come in all skin colors. As a nation, we can no longer afford to waste any of the talent. But avoiding the waste is going require equalizing some treatment in the school and the workplace, some shared responsibility for home and family, and perhaps most important of all, a change in societal attitudes toward girls and women. A little leadership from the top could make a big difference. That task is immense, but the alternative is unthinkable.

Thank you.

Chairman GLENN. Thank you, Ms. Vetter.

Dr. Shirley Malcom, the head, Directorate for Education and Human Resources Programs, American Association for the Advancement of Science, welcome.

TESTIMONY OF SHIRLEY M. MALCOM, PH.D., HEAD, DIRECTORATE FOR EDUCATION AND HUMAN RESOURCES PROGRAMS, AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, WASHINGTON, DC [1]

Dr. MALCOM. Good morning. Thank you very much for the opportunity to come and talk about the issues that relate to the participation or under participation, we should say, of minorities—blacks, Hispanics and American Indians—in scientific and engineering careers.

I am a big fan of puzzles and detective stories. Now, imagine yourself in a detective story. You are a detective who is brought in to solve the case of the leaky pipeline. You are shown a statistical picture of the kindergarten class of 1964. There are a lot of black,

[1] See p. 96 for Dr. Malcom's prepared statement.

Hispanic and American Indian students there. They make up at least 12 percent of that class.

Then you are shown a picture of the Ph.D class of 1988. What you find is that of the 749 doctorates that are awarded in mathematics by U.S. universities, only 341 were received by U.S. citizens, only six of whom were American Indian, black or Hispanic. I want to repeat and underscore this point. Only six Ph.Ds were awarded to black, Hispanic and American Indian citizens in 1988.

One Ph.D went to a black American. Similarly, 4 of 514 Ph.Ds in computer science, 28 of 1,302 Ph.Ds in physics and astronomy, 66 of 2,018 Ph.Ds, in chemistry, 12 of 726 Ph.Ds in earth, atmospheric and marine science, and 66 of 4,190 Ph.Ds in engineering were received by members of these racial ethnic minority groups.

And I would venture to guess that of that 66, a disproportionate share probably came out of Howard Adams Graduate Engineering Programs for Minorities. This is the magnitude of problem that we are facing here.

Now, can we afford these low levels of productivity when minorities become one-third of our Nation at the turn of the century? I think not. Why are the numbers so low at the Ph.D. level? Where did the people go?

Well, one of my bosses, Walter Massey, a black physicist who is the chair of the AAAS board of directors, says that there are so few minority Ph.D scientists because there are few undergraduate minorities in science and engineering, because there are so few who come from high school headed toward science and engineering, and on and on.

Some of the students went to work after they completed the baccalaureate degree. But we know that it wasn't many, because minorities are underrepresented at the baccalaureate levels just as they are at the Ph.D. levels.

Why can't we get more people? I think that the panelists who have preceded me have outlined a lot of the factors that we are facing as to why we can't attract more minority students. Key among those is that we tend, for minority students, all too often to participate in a situation of weeding rather than cultivating.

Rather than taking the students that we have, taking them where they happen to be, whatever they bring in, whatever strengths or deficiencies or anything, and moving them to some place that we perceive they have to go in order to be successful, we participate instead in weeding out rather than cultivating.

We don't retain the minority students who come in with an intention as freshmen to major in science and engineering. We don't retain them to the baccalaureate degree. Maybe if we had 30 more Uri Treismans running around the country trying to help people understand what they are doing to people, we would do a better job of this; but we don't. We have one Uri and one Betty and one Shirley and one of all of us, and unfortunately there is just so much that we can do.

That is why we have to have things that multiply the effect of what we can do to provide the technical assistance to help people understand how they, too, can put something into place that can intervene, that can keep nature from taking its course.

One of the things it is important to realize is that what we are dealing with is a total systems problem which is going to require a total systems solution. There are problems with regard to teachers. There are problems with regard to the way that our schools are structured. There are problems with regard to curriculum. We have no idea what we want our young people to know and to be able to do. We cannot yet articulate it, and we cannot teach that to which we have not ourselves committed.

There are problems with regard to just vesting the concerns in schools, because learning does not only take place in the school; it takes place as well in the community and in the home. And we have to have a coordinated approach that reaches out to all of those places so that children are enabled to learn, that they are given the opportunity to learn.

Today we are holding a meeting at AAAS, a training session for a group of ministers and lay persons who are participating in the AAAS Black churches program. They are running math and science programs after school, on Saturdays. Many of them have community computer learning centers that are there in their churches as a part of them. They are trying to reach out into communities to make a difference. We have to multiply that effort and multiply the effort of all of the other groups that are out there who are concerned about the education of black, Hispanic and American Indian kids.

We are not going to solve these problems working independently of each other. We all have to do our part, but we must do it in the context of a coherent strategy. We are going to have to bite the bullet and say, "our system is failing." But we are also going to have to realize that in so many of these cases it is not our children who need fixing, it is our system.

We have programs that are out there, hundreds of them, thousands of them. Betty Vetter mentioned some of them. We have listings of a lot of them. We need more of them, but we cannot ignore the formal educational system. We can never create enough informal programs to replace or substitute the formal educational system.

But the informal programs are instructive; they give a message; they teach us a lesson that we have to listen to. When you have academically competent people teaching who are enthusiastic, who care about their subject, who expect all of their children to learn; when you provide high expectations and an opportunity to engage in science discovery and in mathematics learning, these children respond.

I think that our historically black colleges and universities and our institutions serving Hispanic and American Indian students in substantial numbers have taught us that when a nurturing and cultivating strategy is employed, those students respond. We know what we have to do. Now we must have the leadership and the will and the commitment to move forward with that knowledge.

Thank you.

Chairman GLENN. Thank you very much. Thank all of you. I wish we had several hours here.

Let me try and simplify this a little bit and find out if I am completely off base on some of this. I mentioned earlier, kids tend to

rise to the level of expectation. And we talked about the Asian kids; there's an assumption that they are good in math "automatically." No, it isn't necessarily that. It is the fact that the Asian kids by and large have a very cohesive family unit and the families expect it out of them.

What you, Dr. Treisman, in effect do at Berkeley—and I read background material on what you had done there—is very interesting. You did not take the remedial approach—that you are a dummy, I'm going to prop you up in this area here.

You took the opposite approach that said, okay, we are going to have a workshop for excellence. It wasn't remedial; it was how excellent can you be. In some ways you are sort of filling the family role there. You are an absent family unit, if you wanted to oversimplify it. Does that oversimplify it?

Dr. TREISMAN. I think another member of the family. I think there is a little danger in thinking about it only as a question of examinations. It is true that children rise almost to the level of expectation, but there also has to be substance. There has to be substance.

The human species, as Carl Sagan said, wants to understand. If there are rich environments in which students can learn and there are expectations that they will do so, everything I have seen in my life as a teacher shows that students will respond.

Chairman GLENN. Any of the rest of you want to comment on that?

Ms. VETTER. I think he is absolutely right.

Dr. MALCOM. Absolutely.

Ms. VETTER. They will also respond in the opposite direction. If you are assumed to be incapable you will reach the level of incapability that you are assumed to have.

Chairman GLENN. See, we get torn two ways here. We are developing new curriculum, we are doing all these different things here on curriculum. There has to be the substance there, I grant you that. But then you make a very powerful, powerful case with the examples of some teachers that just by the dynamics of their teaching are centers of excellence beyond anything you would normally expect out of whatever the curriculum is or is not in particular schools. You point out a half a dozen schools in the United States, high schools that you know of that are supply points for kids that——

Dr. TREISMAN. But these teachers learn—if you look at Garfield, in the early days they started with the worst kinds of instructional materials, crank and plug, rote drill. They liked it, their students liked it. And they discovered a year or 2 in that their students couldn't do anything. And they were forced to figure out—in their words—how much time they could buy to free themselves from the textbooks.

In my case it took 3 or 4 years of realizing that I could help students get A's in calculus. That was relatively easy. Helping them really to come to the next level of doing mathematics required that I rethought what calculus was about. Our college courses were compressed post-Sputnik. They were essentially sorting and selecting devices designed in a time of surplus.

No student with intellectual integrity can learn physics from college physics courses. It comes so quickly that you can only learn it formally. So they are really twin problems. There is the question of constructing academic community, of providing teachers who have the freedom and the ability to actually teach and to work with kids, and on the other hand there is the question of substance.

Chairman GLENN. How important is this spreading out the whole process of math and science education that was mentioned earlier today so that is an ongoing process through a number of years, rather than taking kids up to a point and then saying, bang, you are now immersed in this and then you are out and immersed in something else?

Is that a very important factor or is that a minor factor?

Dr. TREISMAN. In the middle. It is an important significant factor.

Chairman GLENN. Ms. Vetter, what do you think?

Ms. VETTER. I agree that it is an important significant factor. It is not the only one, but I think it would make a lot of difference. We bring children in too fast and send them back out too fast, from math, from science. They are expected to learn all the physics they are going to get in 1 year, and so many of them don't even approach physics.

Chairman GLENN. Are the testing programs valid—you heard the conversation here a moment are—are the testing programs valid that compare our students with other students around the world?

Ms. VETTER. Oh, yes, I think they are.

Dr. TREISMAN. I believe that, unfortunately, they are, and that sometimes teachers are defensive about this and look for—in Chicago the average third grader some years ago tested at the level of—third grade black student—tested at the legal of mental retardation. And the response of the community and the teachers was test bias. Well, maybe three points. I mean, it is an order of magnitude, three orders of magnitude.

Chairman GLENN. Well, if the test scores are valid, then where are we going wrong? Is it in the teaching then? Do the foreign teachers have a better grasp of things? Do they motivate? Do they do the things like you are talking about? Do they have more expectation their students?

What is different then? Because in foreign nation's they have black kids, they are native Indian kids, they have all sorts of kids. So we can't say that that is our big difference.

Dr. TREISMAN. It is clear that the Soviet Union has roughly the same kind of diversity that we do.

Chairman GLENN. Well, not quite as far as minority—it is a different minority representation, but they have some minorities, yes.

Dr. TREISMAN. They have many minorities. It is not a question of diversity, I think. I think it is also clear that none of the countries in the world is doing especially well. I mean, the differences are there, but there don't seem to be students who are really excelling in the large.

But I think that it is a problem of numbers of hours and numbers—just raw numbers of hours of instruction, the working conditions of teachers, the things that teachers are responsible for. If we look in communities now ethnographically, studying the black stu-

dents, we see them coming home and watching Divorce Court. We need in fact to rethink how many hours of schooling there needs to be.

Chairman GLENN. Does that get back to family expectations then, family control, family dictating what the kids are going to do when they are out of school?

Dr. TREISMAN. I think that if schools in many communities were 8 to 5, mixed with daycare, and were year round, there would be enormous support.

Dr. MALCOM. You know, one of the things that we have seen is that a lot of these after school programs in fact provide the kind of alternative. Where the alternative exists, the kids actually flock to it. It is not a matter that they are looking to go to see Divorce Court, it is just that that is the only thing that is there.

If there were other things that were there, other options for engaging in meaningful activity, I think that in fact they would do that. You asked the question about the international comparisons and whether they are valid and what are we doing wrong. One of the things that I see, quite frankly, is that we don't actually give our kids the content that would be needed to answer the questions to perform well on those tests. We have so dumbed down and reduced the curriculum to a point where they don't get what they need to make sense out of the things that are asked on the examination.

We have to have a relook at the curriculum. I think that people like Jaime Escalante and Uri and other teachers who are out there are successful in spite of the curriculum and, in fact, have to ignore it in order really to make the kinds of progress with the students that needs to be made.

We do have to do something with that content, because everyone is not that kind of teacher. Most of these children will not be served by heavy hitters. They are going to have regular people who have to somehow provide the students with the opportunity to learn the subject matter that we think is important and is necessary to be successful and productive within the work force and as citizens.

Dr. TREISMAN. I think it is opportunity to learn, that's the largest factor that we can influence. If students see—looking at the National Assessment of Educational Progress and going back and studying what students have seen at varying levels of performance, students who have seen good mathematics and science do very well on mathematics and science tests. Students who have workbooks, drill and practice, do very poorly.

Chairman GLENN. Should we be putting a lot more into teacher education?

Dr. TREISMAN. Absolutely.

Chairman GLENN. Teacher qualification, teacher standards?

Ms. VETTER. Absolutely. We did something totally unintentional when we decided to open the world to women so that they could be something besides a nurse or a teacher, which is the only thing we used to let them do. And we didn't realize that what would happen is that we would lose this cadre of dedicated teachers because they would now be able to go do something else, and we didn't make up for it.

Well, as the teachers got worse and worse and we, of course, were trying to grow more teachers very rapidly because our students were increasing, and the teachers did not keep up, so we started paying them less and respecting them less, and this went in a vicious circle where the teachers got down to the quality that was so exceedingly poor—and many of them are still in the school system.

Now, we are going to lose a lot of the rest of those in the next 10 years simply because they will get old enough to retire. But if we don't do something very intensive to make sure that their replacements are able to do a better job, I think we can send the whole thing down the drain.

Dr. MALCOM. I think that there is a key issue also in the fact that as the minority student population is increasing, the minority teacher population is decreasing. Now, that is not to say that every minority kid needs to be taught by a minority teacher, but I think that it sends the wrong message to the minority kids as well as to the majority kids when you do not see minority teachers. And I think that this is something that we are really going to have to deal with.

Chairman GLENN. Is that your experience, too, with these groups now? For instance—and I don't want anybody to misunderstand this—if you take a couple of black kids, and you have a group of 20 and you have got some Asian kids and others, does race play a factor in their acceptability back and forth. Do the Asian kids go for an Asian academic excellence group that they bat ideas off of, as you describe in the literature, and if a black kid comes into that he is not accepted by that gr- p. And vice versa?

Dr. TREISMAN. I think, unfortunately, on average it is true, and it is sad. It reflects a failure of our society. I certainly had to work harder to reach out to my students to make it possible for me to really interact with them as human beings. And the fact that there are no black faculty——

Chairman GLENN. Unfortunately, there are a lot of hurdles we are not over yet, obviously.

Dr. MALCOM. Well, you know, one of the things that makes that tough is that when you are a black student in a physics program, for example, at a majority institution, in all likelihood you are the only one. You have no one to study with. You don't have a support system. You have to find your support system some place else. This is often true with women too. When you have this isolation, it makes it tough. If you can reach critical mass, get enough people so they can support each other, you are usually in pretty good shape.

Chairman GLENN. We are on a vote—and I hate to end this even though we are way over time here—but we are on a vote and we are down to our last few minutes. So I have to go for the floor here.

We appreciate you all being here this morning. It has been very interesting. We obviously need a day for each one of you here, not as a panel. So thank you all very much, we appreciate it.

The hearing will stand in recess subject to the call of the Chair.

[Whereupon, at 12:30 p.m., the Committee was adjourned subject to the call of the Chair.]

APPENDIX

STATEMENT

BY

SENATOR MARK O. HATFIELD (R-OR)

ON

THE CRISIS IN SCIENCE AND MATHEMATICS EDUCATION

BEFORE THE

GOVERNMENTAL AFFAIRS COMMITTEE

UNITED STATES SENATE

FIRST SESSION, 101ST CONGRESS

November 9, 1989

(53)

Reform in Science and Mathematics Education:
Strength in Numbers

Mr. Chairman:

Let me begin by thanking you for the opportunity to appear before this Committee today to share some of my thoughts on one of the most troublesome problems facing our nation: the fate of our children in an increasingly technological world.

While I have spoken often on this subject, I have not had the pleasure - as I do today - to testify at a Congressional hearing devoted solely to the subject of science and mathematics education reform. I commend you, Mr. Chairman, and your committee for convening today's hearing, and I look forward to a morning of constructive discussion.

Mr. Chairman, the United States faces a supply and demand crisis. Simply stated, our demand for scientists and engineers is outstripping our supply. Since 1976, the demand for scientists and engineers has increased 85% in every sector of our economy.

In fact, the Bureau of Labor Statistics reports that an average of 138,500 jobs requiring engineering degrees will open up in every year between 1982 and 1995. Yet a declining quantity of young people, particularly women and minorities, are interested in pursuing careers in engineering, science and mathematics.

Today we stand at crossroads, as a true emergency in science and mathematics education takes shape all around us. For example, 67% of all elementary school science teachers fail to meet the National Science Teachers' Association's minimum certification requirements, and 75% of science teachers in grades 7-9 fail to meet those requirements.

Of the nation's 24,000 high schools: 7,000 offer no physics course, 4,000 offer no chemistry and 2,000 offer no biology. Of the high schools which do offer science courses, the proportion that also offer "hands on" laboratory work has dropped from 53% in 1977 to 39% today. Moreover, one in three high schools does not offer enough math to enable even the best students to enter engineering school.

The result is that our children are not competitive. A 1985 study of 8th graders in 20 countries found the United States ranked 10th in arithmetic, 12th in algebra, 16th in geometry and 18th in measurements. And in a 1986 study of college-bound high school seniors in 13 industrialized countries: American students were 9th in physics, 11th in chemistry, and dead last in biology.

Despite the rising demand for scientists and engineers, our children are increasingly uninterested in these fields -- or do not have the skills to pursue the necessary education.

The percentage of college freshmen choosing to major in engineering has declined 21% in the last 10 years, while the percentage choosing to major in computer science has declined 75 percent. And in 1986, 55% of all doctoral degrees in engineering awarded in the United States went to foreign students, and 23% of all doctoral degrees in science went to foreign students.

To further exacerbate the problem, our changing demographics are startling. Blacks and Hispanics currently make up 20% of the United States population, but account for less than 2% of doctoral degrees in science and engineering.

By the year 2020, these two groups will make up one-third of the American population, and yet we are failing to incorporate them into the science and engineering pipeline. Today, 83% of the 22 year-olds in the United States are neither white nor male and the percentage is increasing; we must tap into that pool.

Unless something is done now, we will need 300,000 new science and mathematics teachers at all levels by 1995. By the year 2000, we will face a shortfall of 700,000 scientists and engineers. And we remain unable to fill the science education pipeline with an interested and diverse student population.

This supply and demand crisis -- and it is a crisis -- has implications for virtually every national and international challenge we face today: productivity here at home, competitiveness abroad, and for our national security -- not just

bombs and bullets, but health, housing, and the education of our children. The competition for the limited pool of scientists in the future will ultimately touch every one.

The responsibility for addressing this problem does not rest solely with the federal government - it must involve the private sector as well as the vast array of local, state and federal resources throughout the nation. We need strong national leadership on behalf of science and technology within the federal government, which I believe we have found in the President's Cabinet-level Science Advisor.

Strong leadership is also needed in budget negotiations to prevent budget cuts from colliding with R & D funding, especially non-defense R & D. Most importantly, strong leadership is needed in education: if our children's science and mathematics skills do not improve, all the increased focus on science and technology will be pointless. And I believe we must look first to the elementary classroom.

But the federal government does have a responsibility to leading the effort to improve our educational resources. To this end Mr. Chairman, you and I have been working together to develop a framework for the federal government to address the deficiencies in science and mathematics education. We will soon be introducing two bills

One bill establishes a permanent, federal interagency coordinating council to provide coordination and enhancement across the federal mission agencies in science and mathematics educational activities and opportunities. The second bill, which will be discussed here today, offers a comprehensive strategy to enhance education in these subject matters through out the nation.

We are proposing a national network of regional consortiums - consortiums in the true meaning of the word - a bringing together of existing resources in nine different regions throughout the United States. The mission of the consortiums will be to provide technical assistance and dissemination of resources to large and small, urban and rural, school districts throughout their boundaries. We propose involvement of both formal and informal education structures, higher education, teachers, administrators, and the private sector.

Our bill establishes a national clearinghouse of science, mathematics, and technology education materials. This important mechanism will provide linkages not only between the nine consortiums, but within communities by utilizing on-line computer capability to simplify access to state-of-the-art curriculum and teacher enhancement resources.

Finally, our legislation will provide key support to the informal science education community for further development and enhancement of interactive "hands-on" science exhibits. We will reach out to museums, learning centers, libraries and churches. Whatever the structure is which intrigues and teaches the child.

Additionally, in search of innovative model programs, I am delighted that our legislation will include demonstration funding for model programs in space science education, intergenerational volunteer programs with senior citizens, and early childhood science materials for use in Head Start classrooms.

I believe this proposal truly represents strength in numbers - in collaboration and consolidation of resources. The partnerships encouraged by our legislation are critical if we are to adequately address the emerging crisis in science and mathematics education in this country.

I think my colleagues on both sides of the aisle will agree: education is our gateway to the 21st century. I do not mean to suggest that we should focus our attention exclusively on science and mathematics education - whether it is geography or history of a hundred other disciplines - all education at all levels is critical to our future. Our children's future and our nation's future.

But, Mr. Chairman, we must develop a federal blueprint for science and mathematics education reform. Too many times in the past we have sat idly by as small problems became large problems - and large problems became enormous ones. We must not let that happen here. We have identified the problem, and I would like to think that we have begun to develop the solution. What we need is the political will to act. Now.

I want to thank you for your leadership on this issue, Mr. Chairman. I hope that through our united legislative efforts we will be able to chart a new course for the 1990's and beyond for our children to unlock the mysteries of the scientific world.

Statement by

F. James Rutherford

Chief Education Officer

American Association for the Advancement of Science

Before the

Committee on Governmental Affairs

United States Senate

November 9, 1989

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BRIEF BIOGRAPHY

F. James Rutherford

Current position: Chief Education Officer of the American Association for the Advancement of Science. At AAAS he has initiated several national programs in science education, including Science Resources for Schools, Challenge of the Unknown, the national Forum for School Science, Science Seminars for Teachers, Science Education News, and others. He is also, at this time, the director of Project 2061, and a member of the National Council on Science and Technology Education, the Commission on Academic Freedom and Pre-College Education, and other national boards.

Government service: In 1977, appointed by President Carter to be Assistant Director of the National Science Foundation responsible for all science, mathematics and engineering education programs, preschool through postdoctoral, and public understanding of science programs. When the new Department of Education was launched, the president appointed him to be the first Assistant Secretary for Research and Improvement. This position included responsibility for the National Institute of Education, the National Center for Educational Statistics, the Fund for the Improvement of Post-Secondary Education, and the federal programs supporting school and university libraries and the development of educational technologies.

Academic experience: Professor of science education at Harvard University and New York University, and high school teacher of science in California. Co-director of Harvard Project Physics, director of Project City Science (NYU), and director of the Carnegie Science-Humanities Education Project. For these and other professional activities awarded distinguished service medals by the National Science Teachers Association, the American Association of Physics Teachers, and the National Science Foundation.

Education: Elementary and secondary schools of California, and degrees from the University of California at Berkeley, Stanford University and Harvard University.

American
Association
for the Advancement of
Science

REFORMING THE SCIENCE CURRICULUM NATIONWIDE

Testimony Submitted to the United States Senate
Committee on Governmental Affairs
by F. James Rutherford
Chief Education Officer
American Association for the Advancement of Science

November 9, 1989

Thank you for this opportunity to present some ideas on how the nation can go about the urgent business of reforming science education. Our failures in science education are ubiquitous, long-standing, nationally debilitating, and well-known. For too long now, lasting solutions have evaded us. In my remarks, therefore, I will concentrate on suggesting finding solutions rather than on defining, once more, the problems.

My comments are presented in three related sections. The first discusses why it is that our prior efforts to reform science education in the United States have yielded so little success. The second focuses on the curriculum as the centerpiece of reform and summarizes the approach being taken by the American Association for the Advancement of Science. The final section I will comment on the draft bill being proposed by senators Glenn and Hatfield.

I. The Failure of Reform in Science Education

Since World War II, the United States has experienced three major reform cycles centering on science education. The first was largely in response to post-war industrialization, the second to the space race, and the current one to intensifying global economic competition. In each case the country came to believe that our ability to respond effectively depended, in the final analysis, upon radically improving education, especially, but not exclusively, in science and mathematics.

In each recurring manifestation of the "science education crisis," there has been a flurry of action--public and private, local, state and Federal--followed by a tailing off of effort. The net result is not reassuring, for as the studies of the last decade have shown, the nation's schools are failing to produce graduates who are able to participate responsibly in a world

largely shaped by science and technology. Why have the reform efforts not added up to lasting reform?

My answer points more to what we have failed to do than to the failures of what we have undertaken to do, more to how we have gone about doing things rather than what we have done. To be sure, time and again we have taken action: passed state laws to raise standards, funded curriculum development projects and teacher inservice training, created scholarship and recognition programs for science and math teachers, established information and support centers, formed business-school partnerships, put some new technology in the schools, and much else. However, viewed nationally and over time, our approach in all of this has been timid, sporadic, and haphazard.

(1) As a nation, we have viewed school reform as merely a matter of *fixing up the existing system* instead of completely transforming it. All of the evidence--and, indeed much of the rhetoric--calls for a radical restructuring of elementary and secondary education, and yet we settle for patchwork solutions. We have been unwilling, it seems, to accept the notion that significant and lasting reform will take time (a generation or longer) and require a major national investment. Contrast our shortsightedness in education with the vision and boldness with which we undertook the space program after Sputnik and the building of the interstate highway system.

(2) Lacking a strong national sense of the need to completely transform public education, our reform efforts in science education have come and gone in response to drifting public mood. Long before the latest reform measures, whatever they may be, can take root, a complacent public loses interest and the effort dwindles. Our political leaders, most of whom must surely understand how high the stakes are for the country and that reform by convulsion will not work, have failed so far to create a way of sustaining a nationwide reform effort long enough to change the system.

(3) As sensible as they may individually seem at the time, our hundreds of pieces of state and federal legislation and our thousands of (national, state, and local) projects and programs have been as so many temporary patches--and patches on patches--slapped here and there on a sinking vessel. Our approach to reform in science education has been, and continues to be, a hotchpotch: try this and try that, do something here and something else there, start and stop and start again, go one way and go another. This haphazard approach is as inescapable as it is fruitless, given the absence of clear national goals and of a bold national strategy for reform.

While there is much to be said about the first two claims--that our approach to reform in science education has been timid rather than sweeping and sporadic rather than sustained--I will focus my attention on the third--our chaotic approach to reform. (Throughout, I differentiate between national and federal. The former refers to scope, and may include local, state, and Federal jurisdictions, and the private sector as well; the latter refers only to the legislative and executive branches of the U.S. Government.)

A serious effort to transform the American school system nationwide must, I believe, be focussed on the attainment of specified national educational goals and must be part of a carefully thought out national strategy. I do not propose to spell these out--that is the job of Congress and the Administration in collaboration with the states--but to suggest what their elements might be.

National goals

At the recent education summit meeting of the president and the governors, it was agreed that the next step must be to formulate national goals for the schools. This is an important step forward, for the right set of ambitious yet attainable goals will make it possible to bring coherence into our necessarily diverse reform activities. The right set, that is. The temptation will be to set goals dealing such (somewhat) measurable matters as time spent in school, the amount of science and math to be taken by students, the qualifications of teachers, attendance and dropout rates, graduation standards, violence in the schools, class size, performance on standardized tests, etc., and stop there. More is needed.

In addition, the nation needs a clear and comprehensive set of goals spelling out what all children should know and be able to do by the time they complete high school. By this I do not mean what is taught but what residual knowledge and skills remain after the exams are over and the details forgotten. These learning goals should:

cover the sciences (by which I mean the natural and social sciences, mathematics, and technology) and the humanities,

concentrate on the common core of knowledge and skills we expect of all our citizens rather than on that for those students who will go on to the various specialized occupations,

place quality of understanding above quantity of material to be learned so that the schools can concentrate their efforts on what is really essential, and

be cast in a way that makes it possible for curricula to be developed for reaching them and for procedures to be designed for assessing their attainment by schools, school districts, the states, and the nation.

National strategies

If it is to occur at all, the reform of science education in America will require local, state and federal action. But given the extreme disaggregation of resources and authority that characterizes our educational system, it is all the more urgent that there be a national strategy for reform. Otherwise our efforts will continue to be piecemeal, hit and miss, and often at odds with each other. The kind of strategy we need is one having components and characteristics such as these:

It would, as suggested above, call for the identification and promulgation of national goals. All reform measures would then be judged in terms of their ability to contribute to those goals. These same goals would be used to monitor and report national progress (or lack of progress). What can be done to identify and promulgate national goals?

The strategy would be comprehensive, dealing with all students, all subject areas, and all aspects of the school system.

A key part of the reform strategy must be the introduction of new curricula in the elementary and secondary schools. Such curricula should be designed to insure that all students achieve the understandings and skills specified in the national goals statement. They should also help define what changes are needed in the design of learning materials, the organization of instruction, the preparation of teachers, etc. In this operational sense, curriculum reform becomes a centerpiece in the transformation of the education system.

The division of responsibility--who does what, who pays what--would be spelled out among local, state, and Federal jurisdictions. As part of this, a capability for monitoring and coordinating the various efforts needs to be created. Part of the strategy would include reaching agreement on what happens when particular districts or states fail or are unable to carry out their agreed-upon responsibilities.

Responsibilities would be assigned to all of those Federal agencies having a major stake in the quality and character of precollege education. Congress would provide appropriate budgetary resources to each, and some process instituted for monitoring the performance of each. Included would be

Defense, the individual military services, Energy, Agriculture, Labor, Commerce, NIH, the Public Health Service, NASA, EPA, and others in addition, of course, to Education and NSF.

A mechanism would be established for coordinating Congressional action as it bears on the reform of education. With so many different committees being involved in one aspect or another of science, science education, and education in general, it is difficult to formulate comprehensive and compatible policies.

The strategy would include a provision for modernizing the entire education system technologically--every school and classroom in every state. This would call on all that is known about information and communications systems, about learning and teaching, and about the cost-effective operation of complex systems. Such an education infrastructure might be thought of as relating to learning and teaching as does the interstate highway system (with its connections to state and local roads) is to transportation.

The recruitment of the nation's teaching faculty ought to receive special attention. Current approaches, parochial in conception and practice, have failed dismally. Not only do we not seem to be able to recruit enough talented young people into teaching, we are doing even worse in attracting minorities into the profession. This at the time when the proportion of minority students is rising in the schools and science role models are more needed than ever. Something is needed on a national scale comparable to the recruiting effort of the military services. This will involve far more that a few scholarships and lots of pleading.

In all of this, the matter of money cannot be ducked. It is possible, indeed likely, that a new system of education could be more cost effective than the present one, but in order to get such a system it will be necessary to invest substantial capital in changing the system. Simple arithmetic shows that popular truisms, such as "money is not the problem," are beside the point, the point being that it takes capital other than what it takes to run a system to change it. Where is the reform capital to come from? A national policy should make it clear who has to pay for what, and a plan devised for aggregating and dispensing the necessary funds. Simply increasing the budget of the Department of Education may not be the way do this.

Finally time. As difficult as it is, we need a strategic plan for keeping us in the game long enough to implement changes that will survive. Only a long term effort can bear fruit. Programs, projects, and funding must have lifetime

expectations of decades rather than years, and evaluations of effects must not be rushed. The "quarterly profit and loss statement" syndrome is fatal in education, for only a long term approach has a chance to succeed.

Project 2061

In 1981, the American Association for the Advancement of Science (AAAS) became very worried about the situation in the schools of our country. While the AAAS was concerned about the ability of America to produce enough scientists, mathematicians and engineers to meet our future needs, it was especially distressed by the accumulating evidence that few of our high school graduates are scientifically literate.

Believing that the future of America, and the future of American science, as well, depends heavily on the quality of science education of all of our citizens, the AAAS put science literacy at the top of its list of priorities. Using its own resources, and supported by grants from foundations and industry, the AAAS instituted a series of programs and projects (to add to those already underway) intended to help the schools produce scientifically literate graduates. Among these are:

SCIENCE RESOURCES FOR SCHOOLS -- hands-on activities (involving math and engineering, as well as science) for middle-grade students

CHALLENGE OF THE UNKNOWN -- a series of filmed sequences (distributed free of charge along with a teacher's guide) to be used by middle-grade math students in learning quantitative problem solving

SCIENCE SEMINARS FOR TEACHERS -- top scientists meet with small groups of junior and senior high school science teachers to discuss the nature and significance of recent discoveries

SCIENCE EDUCATION NEWS -- monthly review of new projects and developments in science education distributed free of charge to interested scientists, educators, policy makers, and business leaders

SCIENCE EDUCATION DIRECTORY -- annual listing of individuals, national organizations (scientific and educational), and (federal and state) agencies and legislative committees

NATIONAL FORUM ON SCHOOL SCIENCE -- each year AAAS convenes leaders from education, science, business and government to discuss issues in science education and promote action

THIS YEAR IN SCHOOL SCIENCE -- a widely distributed annual publication, based on commissioned papers and analysis of recent data, that focusses on the topic of that year's National Forum

SCIENCE EDUCATION IN GLOBAL PERSPECTIVE: LESSONS FROM FIVE COUNTRIES -- an example of studies published from time to time by AAAS on key topics in science education

But even as AAAS was instituting these programs, it was looking at the bigger picture in science education, including the failure of previous such efforts to result in deep and lasting reform, in an effort to come up with a strategy for change that would work. By 1984, the details of a long-term, comprehensive reform project had been worked out, and, in 1985, thanks to support from the Carnegie Corporation of New York and the Andrew W. Mellon Foundation, PROJECT 2061: EDUCATION FOR A CHANGING FUTURE was launched.

A summary of PROJECT 2061 is submitted as a supplement to my remarks, so I will not go into detail here. Instead I will point out some of its features that bear on the matters before this committee.

The project is comprehensive in several respects. First it defines science literacy in a way that cuts across all of the natural and social sciences, mathematics, and technology. These are so linked to each other and to contemporary life that they need to be considered together. Moreover, it is comprehensive in that it focusses on all grades (in the belief that it will take the full K-12 experience to produce scientifically literate graduates) and will deal with all components of the system (curriculum, materials, methods, teacher preparation, testing, etc.)

Project 2061 is long-term, being designed to take two decades or longer to achieve nationwide transformation of science and technology education in the schools. Because of this time commitment, the project is divided into phases.

Phase I, now complete after three years of work by hundreds of scientists and educators, set out only to define goals--what everyone should know and be able to do in science, math and technology by the time they graduate.

Phase II, now underway, is a three-year effort to design alternative curriculum models for achieving the Phase I goals and to prepare guidelines for action dealing with the other components of the system.

Phase III is expected to take 10 to 15 years to implement the Phase II designs nationwide.

Project 2061 is goal-directed, which is why so much time and energy was invested in defining goals. These are spelled out in the Phase I report, Science for All Americans, probably the most comprehensive description of what constitutes scientific literacy yet formulated.

The project is collaborative. It already engages scientists, mathematicians, engineers, educators, philosophers, historians, industrialists, and policy makers, and in due course parents and other stakeholders will be full participants.

A central feature of the Project 2061 approach to reform is that teachers have a critical creative role to play. They are not being asked to implement curricula developed by others, but to take the lead in designing alternative models. Phase II has been designed to accomplish this.

Design teams have been selected from six different communities representative of the diversity of America. Each team is composed of 20 teachers, 3 principals, and 2 curriculum specialists, collectively cutting across all grades and subject areas.

Over the more than two years that they will be developing their models, the team members will devote summers to the project as well as having four days of release time each month.

Each team will be supported in several ways, including: dedicated work space; computers at home and in the project space; the latest electronic and print materials related to their work; funds for travel to investigate unusual curricula elsewhere and to participate in professional and educational meetings; consultants as needed; and the physical and intellectual resources of one or more collaborating universities.

In developing new K-12 curricula in science, math and technology, the teams are not bound by the constraints of their existing systems, and are free to be as inventive as they wish. Moreover, they are not under the gun to design curricula to cover all of the traditional material but only that found in Science for All Americans. Quality in science education, rather than quantity, is what they are about.

It can be seen from this brief review that Project 2061 incorporates an entirely new approach to reform in science education. Perhaps it can, to some degree, become part of a national effort. At the very least, consideration should be given to adopting the learning goals of Project 2061, as expressed in Science for All Americans, as national goals.

Comments on "The Excellence in Science, Mathematics, and Technology Education Act of 1990"

I would be pleased to meet with staff to go over the proposed bill in detail. For the moment, let me note the following:

1. I agree that a bill (or set of related bills) is needed to "establish a leadership role for the Federal Government in promoting pre-college science, mathematics,and technology education reform." Indeed, given my earlier comments on formulating a national approach to reform, such a move is probably essential.

2. The draft bill, however, is not nearly comprehensive enough to serve that purpose. It calls for the establishment of only two mechanisms--regional consortiums and a national clearinghouse--when in all likelihood many others are also needed.

3. At the same time, more is being expected of the regional consortiums than they are likely to be able to deliver, especially since the funding level, $15,000,000 is so modest, even given local matching. For that amount, relatively few teachers can be brought up to necessary standards of knowledge of science, math and technology and of new methods of teaching that content, let alone all of the other functions listed in Sec. 103 of the draft bill.

4. If this is to be a limited bill, as it might well be and still be worth passing, then it should be sharply focussed on one particular function. Of the choices possible, training classroom teachers might not be the one of choice. It is expensive (as it is generally done) and often futile unless other matters are dealt with simultaneously.

5. But of course the draft bill says, in that section, only that "such activities may include" any of the 14 listed ones. "May," however, softens the bill from a systems standpoint, once again resulting in uncoordinated, patchwork activities that do not add up to a systematic reform effort.

6. Many of the activities called for are already being carried out, though on limited scale. For example, quite a few national, state, and local alliances have come into being in the last decade, and some are quite effective (although most of them struggle for resources). And programs for under-represented in science and engineering are numerous and funded by government agencies and charitable foundations.

7. It is not clear what services the Regional Consortiums and National Clearinghouse would serve that are not already being provided (albeit on too small a scale) by the regional educational laboratories, ERIC, the National Diffusion Network, the Office of Educational Statistics, NSF and other Federal entities.

8. There is no provision to engage other Federal agencies other than the Department of Education and the National Science Foundation. Yet a dozen or more Federal agencies have a great stake in the quality of precollege science education and ought to be required to participate in reforming it.

9. The bill does not have a focus on goals, such as those suggested by the scientific community in Science for All Americans or being developed by the governors. Such an explicit orientation would make it easier to coordinate the activities proposed by this bill with those created by other legislation.

10. Finally, I suggest that the proposed level of funding is out of scale in relation to the proposed activities, as noted earlier, but still more so with regard to the magnitude and complexity of the problem being addressed.

TESTIMONY

TO

COMMITTEE ON GOVERNMENTAL AFFAIRS

OF

THE UNITED STATES SENATE

IN REGARD TO

THE CRISIS IN SCIENCE AND MATHEMATICS EDUCATION

IN THE UNITED STATES

PRESENTED BY

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November 9, 1989

Introduction

The crisis in science, mathematics and technology education in the United States is thoroughly documented by reports, studies, and testimonies of experts. It would be an easy matter to provide the committee with a repetition of the dismal and frightening statistics and data which illustrates the seriousness of this crisis.* But, this has been done over and over again, and it is time to focus on solving the problem.

Let me summarize the most serious part of the problem and its consequences. The problem consists of several parts. The United States is failing to educate its citizens in science and technology. Not only are we failing to provide the essential science and technology knowledge and skills to those citizens who are working in fields other than science and technology, but we are failing even to produce sufficient numbers and sufficient quality of scientists and engineers from our own country. The fact that half of the engineering faculty in the United States now consists of foreign nationals is a stunning admission of our failure to produce graduate engineers. A major part of our problem has been the abject failure of intervention techniques in bringing women and minorities into scientific careers or even in retaining many from minority groups in our schools. Without the proportional participation of women and minorities in the scientific and technical occupations over the next several years, the United States cannot possibly maintain even its current level of defense, competitive edge or economy, much less make the needed improvements.

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* See especially the Science and Mathematics Education Briefing Book of Horizon Research, Inc. (Chapel Hill, N.C., August 1989)

Instead of sporadic intervention for specific population segments, the entire country desperately needs high-quality education for all children. Young people, not just future scientists, should be exposed to a core curriculum of well-designed science and technology courses taught by well-prepared teachers. All young people must remain in science and technology classes throughout high school. This can be accomplished through reform efforts in science instruction and by the development of appropriate curriculum so that all children can succeed in science.

Although some federal support for reform efforts in science education has been forthcoming, such funds are largely serving the purpose of teacher training and research, and development of curricula at the national level. The costs of local adaptations and implementations are far higher and cannot reasonably be supported by local or state governments alone. These are generally one-time start-up costs necessary only until the local school districts can support the normal operating expenses.

Federal Role in the Support of Science, Mathematics, and Technology Education

Let me offer what I believe are reasonable criteria for the federal role in science and mathematics education and indicate which agencies have the appropriate responsibility. When national needs, like defense, competitiveness or the nation's economy, are seriously jeopardized, then there is a federal responsibility to deal with the problem. This situation presently exists in science, mathematics, and technology education. When the problem requires research or the development of

original materials of the kind that can be generalized and used throughout the nation, it is unreasonable to expect these costs to be borne by state or local governments. This is clearly a federal responsibility. If new developments in science, mathematics, and technology education require unusual start-up costs, such costs would be so disruptive of local budgets or even of state government budgets, that at least part of the costs should be borne by the federal government. Once a program for delivery of science and mathematics education is established, then it becomes the responsibility of local and state governments to fully support it. The federal government should not be in the business of providing routine costs for instruction or for routine in-service training for teachers. It is the larger expenditures required to address a crisis, national in scope, that should bring the federal government into the support of science and mathematics education.

Specific Agency Responsibilities for the Federal Role

Now consider the responsibility of different agencies. The two major government funding agencies for science education are the National Science Foundation and the Department of Education. The National Science Foundation has primary responsibility for basic research in science, engineering and in science and engineering education, including research and development associated with instructional methodology or curriculum. The development of original materials is also the responsibility of the National Science Foundation. But, the implementation of new materials that will be used nationwide should be the function of the Department of Education. Also, the retraining of large numbers of teachers for national

implementation of new programs and curricula should be the responsibility of the Department of Education. Basic generic research in education should be the responsibility of the Department of Education. If the educational research is specific to science, engineering or mathematics, then the research should be the National Science Foundation's responsibility. There should be a continuum of responsibility from one agency to the other, with basic research provided by NSF at one end, and implementation of that research for new programs provided by the Department of Education at the other end of the continuum. The same kind of continuum would follow for the relatedness of the research and development or implementation activities from science to non-science areas of education.

Needs of Science, Math and Technology Education

With the federal role established and the appropriate functions defined for the NSF and the Department of Education, let us consider urgent national needs and how they might be met by these agencies. The present National Science Foundation programs provide the base of support for research and development and for teacher enhancement in science, math and technology. What are additionally needed, however, are long-term regional consortiums to disseminate new reform-developed materials and teaching methodologies and a national clearinghouse for such materials and methods. Each consortium should consist of a basic center located at a college, university or existing research and development center. Regular funding should be provided to support the core operational costs of such a center, of which only 5% should be for administrative costs. Regional

Consortiums would identify, adapt, disseminate, and implement science, mathematics, and technology education instruction materials, teaching methods and assessment tools for use in elementary or secondary schools. Regular funding should not include funds for research or development. Such consortia or centers should seek support from the National Science Foundation or the Department of Education competitively with other groups for these additional funds and expand or contract their staff according to the funding that they receive. Thus, the federal responsibility is to maintain the centers as a support service to their region, but the quality of the research and development programs at each center determines that component's size and likely impact. Such centers should be funded for periods not to exceed five years with renewal possible. It should be possible for new centers to be created at the end of each of these periods and for some existing centers to cease to function. Such a consortium or center must have as its focal point a fiscal agent which would be the college, university, research center, or other similar institutions, associations, or organizations. In addition, it would include school districts or schools, business and industry, and parent groups. Consortia such as these should play a major role in implementing reform in pre-college science, mathematics, and technology education. Federal funding should start at 75% and be phased down to the level of 50% over a four or five-year period. Cost sharing should be from state governments, local schools, and the private sector.

The National Science Teachers Association, the National Council for the Social Studies, and the International Technology Education Association are spearheading major reforms in science, mathematics, social science and technology education that will increase the competence of U.S. citizens in science and technology.

With funding from the National Science Foundation and the U.S. Department of Education, the National Science Teachers Association has launched a major national reform of secondary school science education. This reform, which provides that every child will study each of four well-coordinated science subjects for six years, has received wide-spread and strong support from science teachers, principals, superintendents and 54 scientific societies. (Attached to this testimony as an appendix is a two-page summary of this project, its purposes and its status.)

NSTA Scope, Sequence and Coordination Reform

We are currently establishing consortia, or model centers, with three components. Each center has a college or group of colleges and their associated scientists and science educators working together. Each has a local school or school system including the science teachers involved. We are also seeking the participation and support of the private sector in these local areas. These centers are presently assisting in the research and development phase of our reform effort, but, upon the conclusion of this phase, are not available from existing programs to do full-scale implementation within the schools and districts where the centers are located. Full implementation, including the training of the teachers, the selection and assembly of the necessary curriculum materials and the changes required within the schools, will involve a far greater effort and expense than the present small research and development effort at a few local sites. Yet, many of the costs associated with that implementation are normal instructional costs. Thus, they are the responsibility of the local

schools. Some of the costs are the responsibility of the state and federal government. It is in this latter phase that the federal consortia funding would be especially appropriate. With even 50% federal support, a consortium in Houston, for example, could fully implement the reform in all secondary schools in 1993 that will begin with only three schools in the fall of 1990.

National Clearinghouse

Let me comment now on the need for a national clearinghouse for dissemination of reform materials and methodology. Presently, the National Science Teachers Association is serving as the national clearinghouse and coordinating body for our scope, sequence and coordination reform effort. NSTA or a group of organizations with a central facility could provide a comprehensive national collection and distribution point for instructional materials, methodologies, and computer data. An expanded national clearinghouse would be a two-way operation receiving the excellent new materials and information from the various consortia and from the various federal agencies and disseminating those materials throughout the U.S. One important way for this task to be accomplished is through the electronic bulletin board system. (Presently, NSTA has three bulletin boards up and running 24 hours a day, serving thousands of science teachers and educators.) Through such bulletin boards, teachers can communicate and transfer lesson materials back and forth rapidly in a form that can be printed and used immediately. The electronic data bases have the potential of providing simulations of experiments for students, test items to be used by teachers for student evaluation, and new text or

reading material just going through the development phase. The electronic bulletin boards also provide for communications on critical matters like laboratory safety, new local, state and federal programs of support, and information on institutes and jobs. A national clearinghouse should serve as an example of American technology. It should not merely be a distribution point for printed material, films or tapes. New advances in compact disk technology are revolutionizing data storage, retrieval and the mixing of various media in educational delivery. A national clearinghouse must take advantage of this new technology, as well as the computer.

Conclusion

The nation cannot afford to delay solving its problems of science and technology education. The proposed regional consortiums and national clearinghouse are essential to the success of any reform effort. The National Science Teachers Association stands ready to assist the Congress and the various federal agencies to ensure this success.

NSTA Project on Scope, Sequence, and Coordination of Secondary School Science

Project Director - Bill G. Aldridge

Secondary School science courses in the United States not only fail to prepare citizens for our technological society; they are also major filters to careers in science or science-related fields for our best and brightest students. With increases in science requirements for graduation from high school in almost all states, our existing secondary school science courses have gained the additional reputation of contributing to our tragically high dropout rates of more than 29% between grades 9 and 12.

A careful analysis of the existing scope, sequence, and coordination of science subject matter in U.S. secondary schools reveals very serious deficiencies. Needed changes in secondary school science would greatly increase the numbers of children who study science and would produce greater numbers of persons entering scientific and engineering careers. The proportions of underrepresented groups in these careers would also increase. At the same time, the remaining 95 percent of the students would become sufficiently literate to participate effectively in our scientific and technological world. What are these changes, and how could they be implemented in the United States?

How do we make secondary school science accessible to all students? We must attack the major cause of disinterest and failure: the way science courses are structured, sequenced, and taught and the complete lack of coordination among them.

At the senior high school level, the three major science subjects are biology, chemistry, and physics. Geology, earth science, astronomy, other life science courses, and myriad related subjects are offered as well. But NSTA surveys show that the vast majority of high school students who enroll in science take biology, chemistry, or physics.

High school courses in biology, chemistry, and physics are very similar in scope and sequence to their college-level counterparts. Their approach is somewhat lower in quantitative and theoretical terms, but much overlap exists. Both students and teachers see high school science courses as preparation for college science courses. Few students take all three subjects unless they are required to do so or they intend to major in science or engineering in college.

Almost no general students take all three high school science courses because they perceive the subjects as tough and rigorous and believe that only "able" or "college-bound" students are likely to succeed in them. Most high school students simply do not believe they have the ability to learn this material. Most teachers and counselors agree and directly or indirectly convey this opinion to their students.

The recent trend toward raising science and math requirements for graduation from high school has created a severe problem for both teachers and students. To graduate, students must now take at least two science courses. In some states they must take three. What has happened?

In some cases the two- or three-course science requirement is sparking creative responses as schools add new courses and use old courses in other areas as substitutes. The latter include vocational-technical courses and health or nutrition courses. In other instances, when faced with taking biology, chemistry, and physics, many students simply drop out.

The fundamental problem with high school biology, chemistry, and physics courses is that they are not coordinated, are highly abstract and theoretical, do not spend enough time on each subject, and do not use correct pedagogy. In short, we never give students the chance to *understand* science.

There are two important areas of research on learning that are almost totally ignored in the United States. The first is called the spacing effect; the second is research that shows how people must go through certain stages before they can learn abstract material.

The spacing effect is fairly simple. There is overwhelming evidence that if you space out the studying of a particular subject, it is far more effective than if you study it all at one time. For example, if you study a topic in physics one hour per day for a week, that is far better then studying the same topic for five hours on just one day. The United States is almost the only nation in the world that uses the layer cake curriculum of one concentrated year in each of the science subjects, rather than space these subjects over several years.

The second area of research has established that in order to learn complex or abstract ideas, everyone must go through certain stages. The first of these in science involves having concrete direct experience with the phenomena. Only after this, can you use symbols and equations, and only after this kind of concept development, can one interrelate these concepts to form theories, models and abstractions of science. It is this sequence which is missing from U.S. science education.

The following framework has been proposed:

Proposed Example of a Revised Science Curriculum For Grades 7 Through 12 in the United States

	Grade Level						Total Time Spent
	7	8	9	10	11	12	
Hours Per Week By Subject							
Biology	1	2	2	3	1	1	360
Chemistry	1	1	2	2	3	2	396
Physics	2	2	1	1	2	3	396
Earth/Space Science	3	2	2	1	1	1	360
Total Hours Per Week	7	7	7	7	7	7	
Emphasis	descriptive; phenomenological		empirical; semi-quantitative		theoretical abstract		

The framework just described represents a radical reform of science education in the United States. Over 400 school districts have already expressed an interest in it. Six months ago, the National Science Foundation provided the program planning funds and within the last month, the Department of Education has awarded NSTA, Baylor College of Medicine, and the Houston Independent School District, along with the State Department of Education for California, grants totalling $1.6 million to initiate this important reform. Additional centers are needed to allow other schools to make the necessary changes for the reform effort. This framework enables science teachers, with the support of local college or university scientists or science educators, the opportunity to create their own curriculum to meet their own local needs. This can be accomplished while maintaining the essential ingredients of spaced learning in a developmental sequence. Sufficient federal support to the NSF, added to that already provided by the Department of Education, would enable other centers to initiate this important reform.

Most people are able to learn physics, chemistry, biology, geology, and other related subjects. People can learn how these subjects apply to their lives and to society's problems. If we teach science to *all* students in a coordinated way from the concrete to the abstract, with practical applications, our future citizens will be more evidence-oriented. They will know how and when to ask questions, how to think critically, and then how to be able to make important decisions based on reason rather than on emotion or superstition. Science made understandable and

accessible to all will also mean more and better scientists and engineers--and a different mix among them, including larger numbers of such now underrepresented groups as women and minorities.

The Origin of Scope, Sequence and Coordination of Secondary School Science Education

"...the basic ideas that lie at the heart of all science and mathematics and the basic themes that give form to life and literature are as simple as they are powerful. To be in command of these basic ideas, to use them effectively, requires a continual deepening of one's understanding of them in progressively more complex forms. It is only when such basic ideas are put in formalized terms as equations or elaborated verbal concepts that they are out of reach of the young child, if he has not first understood them intuitively and had a chance to try them out on his own. The early teaching of science, mathematics, social studies, and literature should be designed to teach these subjects with scrupulous intellectual honesty, but with an emphasis upon the intuitive grasp of ideas and upon the use of these basic ideas. A curriculum as it develops should revisit these basic ideas repeatedly, building upon them until the student has grasped the full formal apparatus that goes with them."

Jerome S. Bruner
The Process of Education
Harvard University Press
Cambridge, 1960

Commission on Professionals in Science and Technology

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STATEMENT

before the

COMMITTEE ON GOVERNMENTAL AFFAIRS

UNITED STATES SENATE

by

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Commission on Professionals in Science and Technology

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Thank you for the opportunity to appear before you today to discuss the need to recruit and retain more women and minorities into science and engineering, and some of the ways in which that might be accomplished.

Sixteen years after the nation's first assessments of mathematics and science proficiency among 9, 13 and 17 year olds, our children continue to perform below the 1970 levels in every age group, and well below the levels of children in other nations who are our scientific and technological competitors. It is an appalling indictment of current educational and societal patterns that the performance gap in science between 13 year old boys and girls has more than doubled across the five assessments of science achievement, and that the sex gap even at age 9 has increased. By age 17, although young American women show more improvement from 1982 than men, an immense disparity continues to exist.

The large difference in science performance cannot be explained by differential course-taking patterns, but there is growing evidence of continued differential treatment and opportunities for boys and girls in science instruction. Teachers and textbooks, as well as parents and socialization patterns, all contribute to the differences in performance between the sexes.

Although some recent gains are apparent for 13 and 17 year old black and Hispanic students, their average proficiency remains at least four years behind their white peers. More than half of our young people by age 17 are unprepared to enter any occupation requiring technical skills, and only seven percent have learned enough science to perform well in college level science courses.

National test scores such as the SAT and ACT have dropped substantially for both sexes. The increasing numbers of non-Asian minority students score well below whites, and girls, who scored higher than boys on the verbal section of the SAT through 1971, now score 15 points below boys on the verbal SAT and 46 points below in mathematics.

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American girls are told and shown very early in school and elsewhere that they are not expected to be as good in math as boys, and so of course, this becomes a self-fulfilling prophecy. Minority children in many schools get the same message of inferiority and lack of ability.

Although there are some indications that high school students of both sexes are continuing their study of mathematics longer than was true five years earlier, women are not increasing their registration in the advanced mathematics courses required for entry to engineering and the hard sciences (fig. 1). Further, when given their choice of course selection beginning at ninth grade, more girls than boys drop out of mathematics, and non-Asian minorities are considerably less likely than majority high school students to enroll in a college preparatory mathematics sequence.

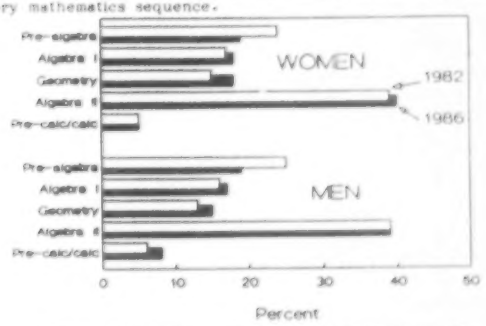

Figure 1. **Highest Mathematics Course Taken by 17 year olds, 1982 and 1986.** Data Source: Dossey: The Mathematics Report Card

But even girls who are mathematically talented are less likely than similarly talented boys to be selected by their teachers for special programs, or even to be recognized by their families as exceptional and provided with a supportive home environment to achieve in mathematics. The University of Minnesota Talented Youth Mathematics Program (UMTYMP) found that girls were substantially less likely than boys to be chosen even to take the qualifying examination for the program when the selection was made by school officials. When found qualified, girls were more likely than boys to reject admission to the program, and once in it, given equal ability and equal grades, female persistence was lower. The lack of appropriate support either from the school or especially from the family, as well as the lack of other girls in the class, were important issues.

"Having a family indifferently request withdrawal of a girl performing near the top of her class while another tenaciously pleads to continue a boy who is struggling, occurred all too frequently," according to the program director, Harvey Keynes. Girls also had to deal with the cultural issues of coping socially with being a smart girl, and with a lack of realization of the impact of mathematics. Issues affecting personal esteem, such as lack of self

confidence in her ability, and lack of involvement in cooperative competitions also played a prominent role.

Women face many obstacles on the way to a science career. The problems begin at birth, with societal assumptions about the characteristics of boys and girls, men and women. Although we have extensive evidence to show that differences in capability, talent and personality are much greater between individuals of the same sex than the generalized differences between the sexes, teachers, parents and society in general continue to assume that little girls, in comparison with little boys, are better at reading, not so good at math, less naturally aggressive, more interested in nurturing, and so on ad infinitum.

Teachers continue to treat girls and boys differently, calling on girls less often, paying less attention to their answers when they have been called on, providing less praise for their ideas, and cutting them off, or allowing boys to interrupt them, before they complete their statements. These well documented differences continue in college, and into the world of work.

Over the past decade and a half, those girls and young women who pushed ahead despite the obstacles to prepare for a non-traditional career in engineering or physical science were allowed, but not invited or particularly encouraged, to do so. The one program set up in the National Science Foundation to support one-day workshops for women to encourage entry into science or engineering was ended a decade ago. Although several of the universities that operated the workshops found them so effective that they have continued them at their own expense, NSF never evaluated the program and present NSF staff either know nothing about it or insist it was ineffective. Today's young women are not generally encouraged to consider careers in science or engineering, and they have never been told that they are capable of excellence in science or that they are needed in these fields.

Non-Asian minorities, on the other hand, have been and are wooed with financial aid, summer preparatory programs, and other inducements which will need to be continued. The patterns of recruitment have not changed, although the reasons for bringing both minorities and women into science and technology have changed considerably. Today, the nation is in genuine need of their services in these fields. One important step in recruiting more women would involve telling them that.

Need for Women and Minorities

Within our shrinking population of college age students, a smaller percentage of freshman each year - both men and women - plan to major in any of the math-based fields of science or engineering where shortages are anticipated. Only in the social and behavioral sciences, where we already have more graduates at this level than can be placed in jobs utilizing their specific education, do we see an increase in the proportion of American freshman women who plan to specialize in the area (fig. 2).

It is not surprising, then, that the yearly increases in the numbers of women earning first degrees in any natural science, and particularly in engineering during the decade of the 1970s leveled off early in the 1980s, and has now started to drop in all of the math-based fields (fig. 3).

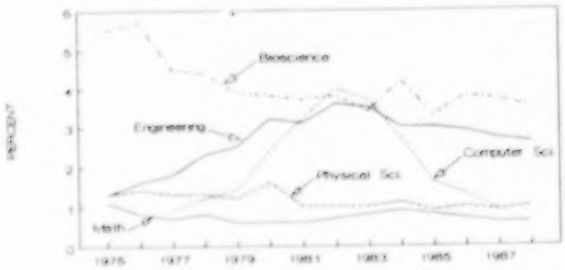

Figure 2. **Percent of Freshman Women Planning to Major in a Science or Engineering Field, 1975 to 1988.** (Data Source: Cooperative Institutional Research Program, University of California at Los Angeles and American Council on Education.)

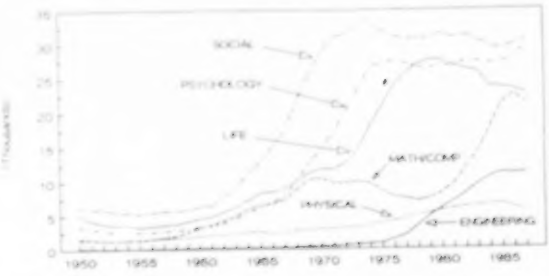

Figure 3. **Number of Science and Engineering Bachelor's Degrees Awarded to Women, by Broad Field, 1950-1987.** (Data Source: National Center for Education Statistics, U.S. Department of Education).

Some of this drop is the result of demographic factors - that is, fewer American births after 1960, resulting in fewer college age students by the 1980s. However, both numerically and as a proportion of graduates, women stopped increasing their presence in science and engineering considerably before they reached parity. In engineering, only 15 percent of first degree awards are earned by women, even in 1988.

The degrees earned by Blacks, Hispanics and native Americans combined is only six percent of all engineering degrees, whereas these groups represent 23 percent of the college age population. In the physical sciences, women are 28 percent of 1987 graduates, and non-Asian minorities 7.5 percent. Only in the life sciences (48 percent), the social sciences (44 percent) and the behavioral sciences (63 percent) are women near or above the half portion that they should represent, even at the bachelor's level. Non-Asian minorities earn only 8.8 percent of all science and engineering bachelor's degrees, and only 7.5 percent of those in the natural sciences and engineering.

At the higher degree levels that are required for professional positions in the sciences, women earn only 27 percent of PhDs in all science and engineering fields, including the social and behavioral sciences, and 21.5 percent in the natural science-engineering fields. PhD awards to American Blacks, Indians and Hispanics combined represent less than three percent of the total. In part, this is because American universities educate significant numbers of graduate students from other nations, most of them men. Indeed, more than half of U.S. doctoral recipients in engineering are citizens of other countries. And even among American doctorates in 1989, women earned only 18 percent of the physical science and mathematics doctorates awarded, six percent of those in engineering, 40 percent of those in the life sciences and half of those in the social and behavioral sciences. Blacks, Hispanics and American Indians combined earned only five percent of American PhDs in science and engineering, and those figures double count the minority women.

While these numbers represent significant increases for women over the past decade, they also indicate that women are much less likely to earn professional level degrees in the math-based fields, such as engineering and the physical sciences, where the nation already is experiencing some shortages. Despite the progress of American women over the past two decades in preparing for and entering the science and engineering communities, their participation continues to be limited in scope, and at every math and science dropoff point in the educational ladder, they are more likely than their male peers to disappear.

Girls are not alone in self-selecting out of mathematics, and thus, often by inadvertence, out of all the math-based fields. Half of all American students take no formal classes in mathematics after grade nine, and half again of the remainder end their math education every year thereafter until age 30 - the usual age for the doctorate degree. As a result of the constant attrition from mathematics, only 141 doctorates in mathematics were earned by Americans in 1988, and only 39 of them were earned by women. Foreign students earned 146 mathematics Ph.D.s in 1988 from American universities.

The National Science Foundation projects a cumulative shortfall of 675,000 bachelors graduates in natural science and engineering fields by 2006. The agency foresees a demand for 24,000 PhDs per year in these fields by 2006, compared with the 9,200 U.S. PhD graduates in 1988. Major reasons for the shortfall include the changing demographics of our population - the drop in births beginning in the early 1960s and the rapid increase in minority children within our school age population - and the deterioration of our public education system that has occurred over the past decade as underpaid and often poorly educated teachers attempted to cope with an array of social ills that affect every aspect of education.

Solutions

There are a number of excellent programs scattered throughout the nation's schools that have been started in the past few years to improve science and math education. The problem is to locate the small, healthy trees in the vast forest of mediocrity and then to make sure that stocks are available for transplant into other school systems that are ready for change. The National Science Foundation, which has funded several of the pilot efforts, should be responsible for determining which ones have proved effective and should be made available on a wider basis.

Several states are moving ahead, both separately and in groups, to institute new educational programs and policies at the pre-college level. Professional groups are working on new curriculum concepts, and industry is providing more and more support for local school systems. All of these activities must continue and in some cases be strengthened.

Women

The Math/Science Network, started at Mills College and now expanded throughout the nation, encourages young women to take a full complement of mathematics courses in high school, and exposes them to science and engineering careers. About 70,000 students participate each year. This excellent program needs to be expanded to the place that every girl has a chance to participate.

The University of Minnesota's UMPTYMP has obtained three year funding from the Bush Foundation for an intervention program that will solve some of the problems in the participation of mathematically talented women. But the problems found for women in that program are surely not limited to Minnesota. A substantial effort is needed to educate parents, teachers, and society in general about the damage done to talented girls who do not fit the societal gender stereotypes. [The damage done by these stereotypes also negatively affects boys who do not fit the molds.]

To reach the important goal of increasing our output of scientists, more women from the shrinking baccalaureate population of natural science/engineering graduates will need to continue with graduate study, and some additional assistance that is not now available is required. Women science graduate students presently are less likely than men, including foreign men in the same field, to have either institutional or federal support during their graduate study; and they are more likely than men to be self-supporting. National fellowships for graduate students have declined sharply over the past decade as researchers, mostly men, have obtained additional funding in their grants to support some graduate students. Typically, male faculty (who receive almost all of the research grants because there are so few female faculty in these fields,) prefer to use male graduate students to help with their research. Research assistantships provide an essential apprenticeship for tomorrow's research scientists.

Women graduate students who have institutional support are more likely than men to have teaching assistantships, which, unlike research assistantships, require extra time from the graduate research program to

prepare teaching materials and in some cases, grade papers. It may be an apprenticeship to teaching, but not to scientific research.

It should also be noted that although the cost of a graduate education is the same, at the same institution, for men and women, their ability to repay loans that may be required is affected by the fact that women are paid less than men once they enter the work force. Among full time workers, women earn less than men with the same degree and experience level in every field of science, and the difference increases with years of experience (fig. 4).

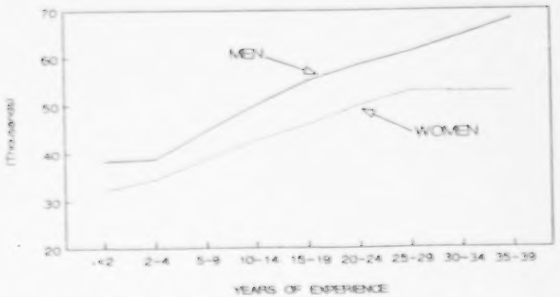

Figure 4. Salaries of Doctorate Scientists and Engineers by Sex and Years of Experience, 1987. Data Source: National Research Council

Women have one additional need, resulting from the fact that their best years for graduate study and for child-bearing coincide. While child care should be a joint responsibility for parents, the reality is that women with small children need additional monetary support to cover child care expenses. Graduate programs in natural science and engineering require long laboratory hours that will infringe on normal homelife patterns.

Lack of funds for child care may require even the best women graduate students to withdraw from a graduate program. The alternative - requiring women graduate students who are not independently wealthy to remain childless at least through graduate school and perhaps the important early years of a postdoctoral career - is an unacceptable choice either for women or for society.

Beginning next year, the National Science Foundation has designated 80 of its 1,050 graduate fellowships as a set-aside for women in engineering. This is a step in the right direction, but it is insufficient. Women have always been eligible to compete for the NSF fellowships (except, in the case of non-minority women, for the 150 that are set aside for minorities) and the new designation will assure that women obtain at least ten percent of the remaining federal fellowships. Women are half of the population and earn 39 percent of the bachelor's degrees awarded in the NSF science and engineering fields. The nation needs more of them trained to the doctoral level.

Minorities

Getting more minorities into science and engineering requires intervention at the pre-college level. Some programs already in place, including particularly such proven efforts as MESA (Mathematics, Engineering, Science Achievement), now concentrated in the west, need continuing support and expansion. Once into college, minority students need additional support programs, such as the Minority Engineering Program (MEP) now operating in most engineering schools, which provides a system of upper class mentoring support for freshman and sophomores, among other things. The federal program of Minority Access to Research Careers (MARC) of the National Institutes of Health is a highly successful Federal intervention program established to increase the number of minority biomedical scientists. More than 800 students and 56 institutions have participated in MARC since 1977, and the track record for the ultimate enrollment of about three fourths of MARC participants in a graduate or professional program is highly impressive. The NIH Minority Biological Research Support (MBRS) program also has been effective to enhance research careers of minority faculty. But the numbers are small.

Most of the intervention programs, if replicated with care and provided with stable funding, can make a substantial contribution to the identification, recruitment and education of minority engineers and scientists.

Intervention is, of course, a bandage for a wound previously inflicted. Minority children disproportionately enter large urban school districts where there are chronic shortages of good mathematics and science teachers, little or no hands-on laboratory science, and most important, low teacher expectations. As with girls, the low expectations become a self-fulfilling prophecy as students avoid the more difficult math and science courses, and consequently attain lower achievement scores than the white and Asian boys.

While the role of the federal government in pre-college education is a limited one, it also can be a vital one. Some of the legislation of the past, if fully implemented, could go a long way to remedy some of the problems of recruiting minority children into science. Even small amounts of educational difference make a significant difference in the outcome. **Head Start** is a proven program which compensates in many ways for the lack of enrichment suffered by many children prior to entering kindergarten. It has been shown that children given the **Head Start** program are far more likely to complete high school, to enter college, to become tax-paying citizens than their peers who did not have this advantage. They are much less likely to be arrested, or to be on welfare (Table 1). Yet, in 1988, only one in five eligible children were served by **Head Start**, due to inadequate funding. Education, including intervention education, pays. It is the alternatives that are costly.

Pre-kindergarten children can be helped if their parents - particularly those of children in poverty - understand the importance of science and math education. Programs stressing parent out-reach, such as the Linkages project of the Office of Opportunities at the American Association for the Advancement of Science, should be supported and extended. Children in large cities, particularly, should be enabled to participate in the informal learning experiences of science museums and library media centers.

TABLE 1

HEAD START: RESULTS, FALL 1984
(Cohort Now 19 Years Old)

	Head Start	Control
Percent Employed	59%	32%
High School Graduates	67%	49%
Enrolled in College	38%	21%
Function Competence	61%	38%
Been Arrested	31%	51%
On Welfare	18%	32%

Source: High/Scope Foundation, Michigan, September 1984

Intervention programs at the level of junior and senior high school also will continue to be required until the nation's school systems are sufficiently repaired to provide every student with the education and skills needed to participate fully in our advanced industrial society. But those repairs cannot be completed without the cooperative and concerted efforts of local, state and federal legislators and officials in collaboration with parents and educators.

America's college age population, from which we must draw most of tomorrow's scientists and engineers, will continue to contract through the mid-1990s. This provides a window of opportunity for young men and women which apparently is not yet visible to most of them. It also provides a real challenge to the nation. We cannot maintain a cadre of bright young scientists and engineers without utilizing the talents of that 65 percent of our young people who are not white and male.

America's talent pool includes equal numbers of males and females who come in all skin colors. As a nation, we can no longer afford to waste any of that talent. But avoiding that waste requires equal treatment in school and the workplace, shared responsibility for home and family, and perhaps most important of all, a change in societal attitudes toward girls and women. The task is immense, but the alternative is unthinkable.

TESTIMONY BY

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AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SUBMITTED TO

COMMITTEE ON GOVERNMENTAL AFFAIRS

U.S.SENATE

9 NOVEMBER 1989

I am Shirley M. Malcom, Head of the Directorate for Education and Human Resources Programs of the American Association for the Advancement of Science (AAAS). I come today as an individual to add my voice to the many others who are concerned about the quality of science, mathematics and technology education in the United States. I appreciate the opportunity to address this distinguished committee.

An upcoming PBS special raises the question, "Who Will Do Science?" Its focus is on the low numbers of minorities in these fields and the implications of this in the face of America's changing demographics.

America is changing. On average our population is getting older. There are declining numbers of college age young people, a trend which began in the early 1980's and which will continue until the mid 1990's (Figure 1). American Indians, Blacks and Hispanics are an increasing proportion of these young people. By the year 2000 minorities will be 47% of the school age population. They are already the majority of the school population in Mississippi and New Mexico (and soon also will be in California and Texas), as well as in our major urban centers. On the other hand, minorities comprise a disproportionately small share of the science and engineering workforce, of doctoral scientists and engineers, and of students intending to major, enrolling or graduating in science or engineering.

In 1988, of 749 doctorates awarded in mathematics by U.S. universities, only 341 were received by U.S. citizens, only 6 of

whom were American Indian, Black or Hispanic. Similarly, 4 of 514 PhD's in computer science, 28 of 1,302 PhD's in physics and astronomy, 66 of 2,018 PhD's in chemistry, 12 of 726 PhD's in earth, atmospheric and marine science, and 66 of 4,190 PhD's in engineering were received by members of these racial/ethnic minority groups, according to National Research Council data.

Low minority doctorate production contributes to low minority faculty percentages; these in turn decrease the number of role models available to minority and majority students (Table 1 and Figure 2). This imparts a message that minorities don't do science or engineering and affects perceptions and expectations for minorities in science and engineering. Low numbers and the isolation that is often born of it feed lowered retention and so on. The cycle is vicious, and its effects are devastating.

In the doctorate numbers we are looking at the trickle of students from the end of the educational pipeline.

To understand why the numbers are so few at the end, we must look to earlier school and college experiences. For only by exploring the barriers can we begin to understand the specific interventions which must be put in place, the interconnections among these elements, and the complexity of the system we must influence.

It is my hope that this will lead us to understand the need to develop and respond to a coherent plan, articulated across all educational levels; to involve all the stakeholders; and to avoid Bandaid responses to system wide problems.

Barriers to minority achievement in science and mathematics appear early. Many of these are related to the fact that minority children are more likely to be poor. These children may have less rich experiences; fewer opportunities to explore phenomena; fewer educational toys; fewer reading materials; and parents whom the educational system may have failed who cannot guide their children's encounters with the world. These parents may be no less willing, but perhaps are less able to provide their children with the good beginnings they need. Quality early childhood education may not be available to compensate for a less rich home environment -- i.e. one that may not include pre-K experiences where children are encouraged to ask "why" and guided in discovering the way that answers are found.

EARLY SCHOOL EXPERIENCES

Ready or not, they go to school. Here minority children often find less experienced teachers and a less rich environment in inner city or rural schools which are inadequately supported. Even in our more affluent suburban schools they are all too often tracked into an inferior educational program. The mathematics that is offered is too often basic skills with little opportunity to develop problem solving abilities. Hands-on science costs money, requires teachers who possess knowledge and comfort in delivering instruction in this manner, administrative structures which support it, and, quite basically, TIME. The deficiencies which students may bring to school are magnified over time as the disadvantage accumulates. The performance gap between minority

and non-minority children increases. Early grouping based on perceived ability (or inability) becomes later tracking, transforming expectations of failure in the reality of low performance. If the students have access to computers it is often for uninspired purposes, in contrast with the potential power of the technology. They are unlikely to see models of American Indian, Black and Hispanic science or engineering professionals. Many know little about how you become a scientist or engineer or about the lifestyle or lifework of such individuals.

HIGH SCHOOL AND BEYOND?

In high school minority students are less likely to take upper level elective courses in science and mathematics, even where they have completed the preceding level with a grade of A or B (Tables 2 and 3). They are less likely to continue on to postsecondary education. Where they do, they are more likely to attend a two-year institution from which transfer to four-year programs, especially in science, is low.

Loans rather than grants dominate the structure of financial aid in college. Where loans from college exceed the families' annual income, minority students may be unwilling to assume this burden of debt, unsure that financial rewards on the other side of the degree will be sufficient to retire the debt in a reasonable period of time. The general barriers in the education of minorities converge with the specific challenges of education in science and engineering, producing the effects of cumulative

disadvantage which are so obvious in the doctoral data.

It must be said at this point that the news is not all bad. Recent research by Hilton and Hsia at the Educational Testing Service reveals that minority students who have high mathematical ability (as measured by scores of 550 and above on the SAT) are as likely or more likely to major in and be retained in science or engineering fields as are majority students. Persisters are characterized by a number of pre-college characteristics that include participation in math or science clubs, exposure to role models, and contact with college-based programs specifically aimed at attracting minorities to science and engineering fields.

Strong academic preparation coupled with specific recruitment and enrichment seems to increase the success minorities experience in science and engineering programs.

Bridge programs that facilitate the transition between high school and college have been demonstrated to be effective in later retention of minority students in science and engineering fields.

Specific interventions to enhance success in calculus by minority students have been demonstrated by Jaimie Escalante with students at Garfield High School in Los Angeles, by Uri Treisman at the University of California, Berkeley and by hundreds of less famous other teachers. There is no secret formula: high expectations; a focus on challenge rather than remediation; working together productively; effort (time on task) and desire; just good teaching, and the belief that everyone (including those

of us who do not fit the image of the scientist or engineer) can learn.

In 1983 AAAS conducted a study of programs designed to increase the participation of minority, female and disabled students in science and engineering careers. This work was done in support of the efforts of the National Science Board Commission on Pre-College Education in Mathematics, Science and Technology. These so-called intervention programs, many of which took place outside of the formal school setting, had tremendous success in improving education for minority students. When provided the opportunity and tools to achieve in science and mathematics, minority students do in fact achieve in these fields. It is instructive to remember that Hilton and Hsia cite the "pull" of specific targeted programs to recruit such students as a finding in their research of high ability minority students who persist in science or engineering.

We found common elements among out-of-school programs that work, that are instructive for our efforts to improve education inside of school. These include: teachers who are competent in their subject matter, who are excited about their subject and who convey this excitement to their students; hands-on involvement with science; project-focused, multidisciplinary work that emphasizes science, math and communications skills; clearly articulated goals; high expectations; contact with role models who convey a sense of the connection between work in school and future careers; and parental involvement.

If we think about it we will realize that no single sector alone will be able to bring about the kind of systemic change we need and at the same time capture the students already in the pipeline. For a long time to come we will need the intervention programs that exist outside of school -- academic enrichment programs run by professional societies, colleges and universities, museums, churches, and other community-based organizations.

But we also need a systematic approach to fixing the formal system of schooling in such a way that it supports learning for all students in science and mathematics.

(1) We must appreciate the complexity of the system;

(2) We must develop a coherent plan for reform of science and math education that begins with setting high goals for all students--what we want students to know and be able to do;

(3) We must seek leverage points that support system wide change; and

(4) We must develop collaborations and connections to the other stakeholders that will promote this system-wide change.

We already have in place strong program models that show us how we might address many of the barriers to participation in science and mathematics which minority students encounter.

PARENTS

Programs such as Family Math and Family Science involve parents and children in experiences which are fun and which support learning. Parent workshops such as the models we at AAAS

have developed explain how parents can support their children's education in math and science, which courses to take, how to negotiate the educational system, etc. Booklets for minority parents such as those developed in a joint activity of AAAS and The College Board Project Equality are made available in these sessions which are sponsored by community groups, churches, clubs, colleges, schools and concerned individuals. ("Get into the Equation: Math and Science, Parents and Children" and "Contamos Con Ustedes")

TEACHERS

Many effective models exist for assisting teachers to provide an excellent and equitable instructional setting for minority students, including activities of the Lawrence Hall of Science EQUALS program, teacher inservice programs of groups such as the Southeastern Consortium for Minorities in Engineering, North Carolina Math Science Education Network, American Indian Science and Engineering Society. Many models also exist as components of a number of the NSF-funded Comprehensive Regional Centers for Minorities and of many other institutions.

The fundamental issue is to increase competence in content, and also to provide teachers with tools, skills and resources related to materials, methods of teaching, ways of adapting, and specific research findings and recommendations on how equity can be achieved in the classroom. They must learn that they often need to add minority role models to their lessons as well as how to do this. They should understand how the culture of their

students may affect the ways they might be taught. They need to understand why parents of minority students need to be involved as well as assisted with specific ideas about how to involve them. In providing inservice to teachers, single minded focus on content will not get us the results we desire.

SCHOOLS

Models of school improvement such as those developed by Dr. James Comer in New Haven give ample evidence that schools can be helped to work for all children. If we assume that the will exists, specific strategies are known that enable such changes to occur. Effective science/math and engineering magnet programs can be found across the country, including in our inner cities. The challenge is in making more widely available what we know about changing schools and developing programs and being assistive in applying these to entire systems.

STUDENTS

Programs exists that provide direct intervention with students. These serve children as early as the primary level in efforts such as the Saturday Academy (which was developed in 1978 by the Atlanta University Resource Center and which has been adapted and spread to many other institutions in the intervening decade. DAPCEP (Detroit Area Pre-College Engineering Program), the American Indian Science and Engineering Society and the Puerto Rico Resource Center have promoted participation in science projects and sciences fairs to develop interest by

minority students in science. Project SEED and the American Chemical Society as well as many of the federally funded research and development labs have provided summer research experiences for minority youth. Summer camps and comprehensive summer programs are sponsored by many different organizations. Academic year programs attempt to connect to schools, providing enrichment, role models and counselling to students. Among the array of programs one can find "Explainer programs" sponsored by museums, comprehensive after school science programs, such as the Science Skills Center in Brooklyn and pre-college minorities in engineering programs such as MESA, PRIME and PRISM.

These are programs of high quality and high expectation. In spring 1989 16 students, ages 10-13 from the Science Skills Center took the N.Y. Regents examination in biology. That is, minority students in 4^{th} - 7^{th} grade took a 10^{th} grade examination. All 16 students passed the Regents, the youngest to pass in the history of the exam. All 16 are now taking Advanced Placement Biology. When they pass the examination next spring they will be in middle school with college credit. These programs are rigorous and the expectations are high. But unlike too many of the schools which such students attend they provide an environment to learn which is ripe for success.

As the efforts toward education reform are mounted, it must be remembered that learning must occur in the community and the home as well as in the school to be maximally effective for minority youth. We must recognize the role of and provide

mechanisms to support out-of-school programs.

Programs also exist that have proven effective in overcoming the considerable obstacles that exist at the college and graduate levels. Many of the Historically Black Colleges and Universities and institutions serving significant Hispanic and American Indian populations have demonstrated that minority students can be successful in rigorous science and engineering programs. Using such strategies as bridge programs between high school and college, peer counseling through student chapters of minority science and engineering societies, regular faculty contact and monitoring of student progress, and early exposure to research, minority students are being retained. In essence, a strategy is employed to nurture and cultivate rather than weed students out.

GEM (Graduate Engineering Degrees for Minorities), NIH Minority Access to Research Careers and other such programs suggest that it is possible to impact graduate education for minorities as well.

CONCLUSION

We have been slow to recognize the threat that is posed by failing to develop a dwindling talent pool -- a talent pool which is very different from that which we drew upon in the post-Sputnik years. American Indians, Blacks and Hispanics can and must be a part of the solution to America's need for scientific and technological talent.

Tinkering around the edges will not help us maintain a world-class scientific and technological enterprise. We must

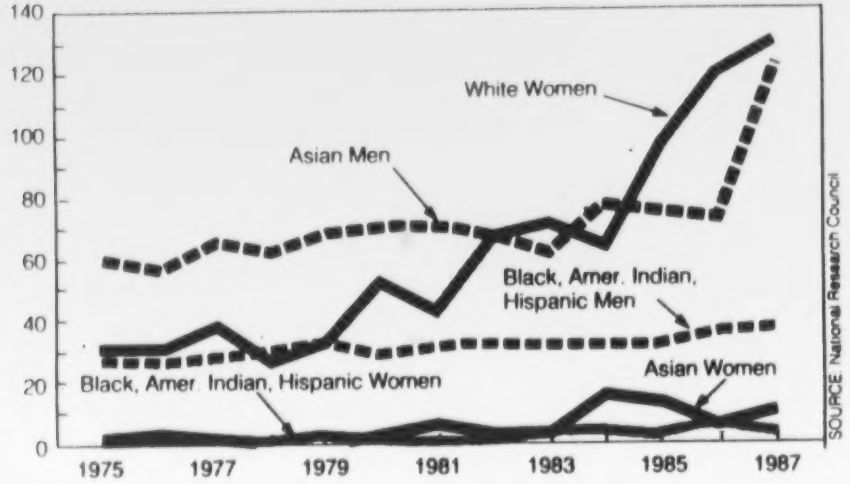
rethink and restructure the system for the production of scientists and engineers from pre-K through graduate education. What needs to be done? Two tasks are primary:

(1) The agencies and departments of the federal government must find targets of opportunity around a single coherent plan. The final report of the Federal Wide Task Force on Women Minorities and the Handicapped in Science and Technology, on which I serve, can be a focal point for discussions of cooperation and collaboration which need to take place. Gaps in programming need to be identified and filled by the appropriate agency or department.

(2) Congress must support these efforts. We would encourage the Congress to look at the need for legislation to support improved science, mathematics and technology education in a manner similar to the way it approached the Omnibus Trade Bill. The way in which legislative responsibility and oversight for education is currently divided does not easily allow for development of a coherent legislative strategy. We call upon the leadership of both Houses of Congress and the very competent leadership in this Committee to assemble a Congressional summit on science, mathematics and engineering education, to extend the dialogue and to model for the agencies and states the way to develop a coherent policy. Everyone has a part to play in configuring and implementing a solution. The AAAS stands ready to assist in whatever way we possibly can.

Figure 1

Figure 2.



U.S. minority Ph.D.s in engineering, 1975–87.

Girls can count on math careers, students told

By SCOTT WADE
Of The Morning Call

Yes, there are mathematicians who spend long hours in stuffy offices, scratching their heads and sharpening their pencils late into the night.

There are also mathematicians who work in Tanzania trying to figure out how many elephants a park will hold without turning a vegetated landscape into a desert.

Mathematicians work on projects such as solar heat, high speed magnetic trains and tracing neuron patterns in the brain with the help of computers.

Seventh and eighth grade girls from 16 schools in the Lehigh Valley spent yesterday at Cedar Crest College at a special event called MathConn '89. Cedar Crest professors Dr. Regina Brunner and Dr. Charles Chapman, along with other teachers from the area, have been organizing the event since last summer.

Two nationally known women mathematicians told about 200 Lehigh Valley students yesterday not to believe friends who say girls aren't good at math or that it's impossible to be a good mother as well as a good scientist.

They also said that most science careers require a strong foundation in math — even careers in "soft sciences" such as biology, ecology and economics.

Brunner said she and her colleagues created MathConn '89 to address a declining number of American students studying for doctorates in math. Beyond that, she hoped to address the fact that fewer than one in five math doctoral degrees in America go to women.

The two main speakers yesterday were Dr. Lilian Shiao-yen Wu, a native of Beijing, China, and now a mathematician for IBM in New York City, and Dr. Linda Petzold, a numerical analyst at Lawrence Livermore Laboratory in California.

Petzold said a numerical analyst uses mathematical methods to solve scientific problems on computers. To demonstrate how math can be applied to situations normally considered outside the math field, Wu presented a brief slide show of her work in Tanzania, where large elephant herds were overwhelming areas of a national park.

The scientist drew laughs in describing how a tree had been badly scarred by an rambunctious elephant.

"Most of this kind of damage is done by teen age male elephants, they're the rowdy bunch," she said. "When they're crowded, they really start knocking trees down."

Both women said advanced mathematics consists of simplifying larger problems into understandable formulas.

Petzold said she and others use math formulas in conjunction with computers that can save companies hundreds of thousands of dollars. For example, rather than building an expensive prototype of a new model of car, the design can be done by computer.

She said some car companies can simulate how a car will react on a bumpy road or how pollutants can be removed from fuel.

"If you don't like math, don't do it," said Petzold. "But if you do like math, don't reject it because you are a girl."

The Morning Call
Allentown, Pennsylvania
6 April 1989

BACK TO BASICS

Proficiency levels of students, age 13

Scale (0-1,000) based on performance of certain standardized tasks

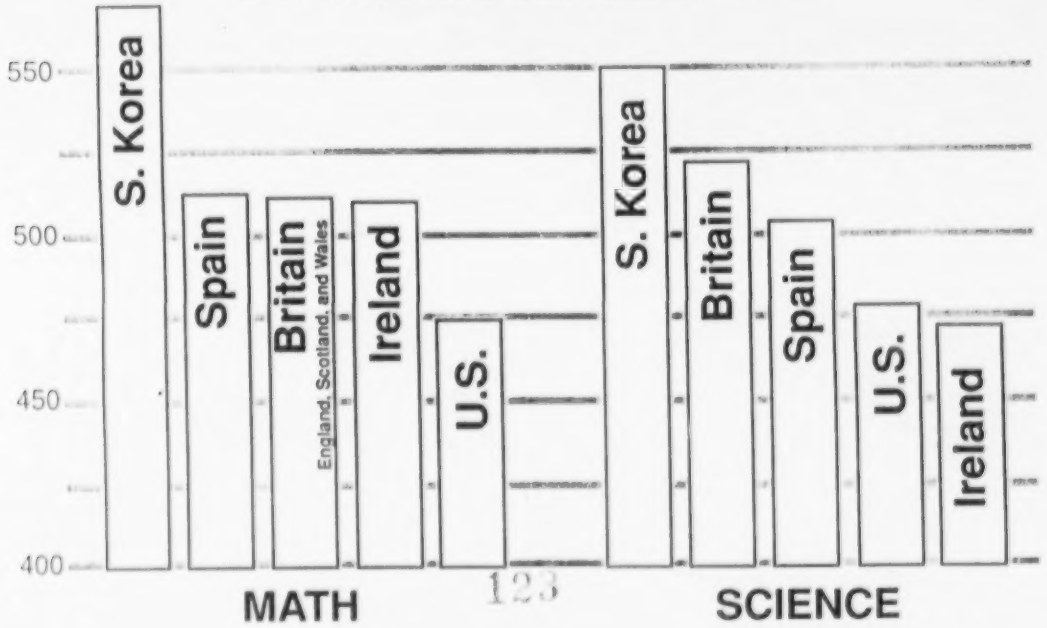


Table 1

Full-time Faculty at Research Universities, by Selected Characteristics, 1986.

Department	Total Faculty	Female	Black	Hispanic	Asian
Engineering					
Aeronautical	538	8	5	10	58
Chemical	1,232	34	9	31	117
Civil	2,017	44	12	42	228
Electrical	3,137	90	18	33	439
Mechanical	2,310	39	11	14	274
Computer Sciences	1,415	125	11	33	130

NOTE: Survey respondents were doctorate-granting departments at the 181 doctorate-granting universities reporting research expenditures of $2.15 million or more in fiscal year 1983. Numbers of American Indians were too small to permit correction for non-response.
SOURCE: National Science Foundation, SRS

Table 2

Percentage of 1982 High School Graduates Who Went on to Next "Pipeline" Mathematics Course After Completing the Previous Course

	Percentage that took geometry after passing algebra	Percentage that took algebra II after passing geometry	Percentage that took trigonometry after passing algebra II	Percentage that took calculus after passing trigonometry
Sex:				
Males	67	55	43	31
Females	63	52	34	30
Of those earning As or Bs on previous course, by sex:				
Males	82	82	55	47
Females	74	81	45	41
Race/ethnicity:				
Hispanics	50	47	28	28
Black	57	55	29	29
White	67	54	40	30
Of those earning As or Bs on previous course, by race/ethnicity:				
Hispanic	64	56	45	48
Black	74	82	48	31
White	79	82	50	43
Urbanicity of school:				
Urban high school	65	55	38	25
Suburban high school	69	52	40	33
Rural high school	58	55	39	26
Regional differences:				
New England	76	78	32	50
Mid-Atlantic	64	54	48	40
West North Central	66	45	32	9
West South Central	53	62	32	19
Curricular track:				
General	52	41	27	9
Academic	82	81	45	38
Vocational	43	35	19	11

NOTE: The source from which this tabulation is derived does not include the total numbers of students in these samples. Also the data as originally reported do not indicate the actual order in which the courses were taken, only that the students had taken these courses before graduating from high school. To this extent the tabulation forces an artificial formatism on the order of course-taking.

SOURCE: C. Dennis Carroll, *Mathematics Courses Taking by 1982 High School Sophomores Who Graduated in 1982* (Washington, DC: U.S. Department of Education, National Center for Education Statistics, April 1984).

Table 3

Percentage of 1982 High School Graduates Who Went on to Next "Pipeline" Science Course After Completing the Previous Course

	Percentage that took biology after passing general science	Percentage that took chemistry after passing biology	Percentage that took physics after passing chemistry
Sex:			
Males	72	39	47
Females	75	37	31
Of those earning As or Bs on previous course, by sex:			
Males	79	59	61
Females	79	60	40
Race/ethnicity:			
Hispanics	71	21	33
Black	74	28	27
White	74	42	40
Of those earning As or Bs on previous course, by race/ethnicity:			
Hispanic	75	32	43
Black	78	43	41
White	79	57	51
Urbanicity of school:			
Urban high school	72	33	39
Suburban high school	73	41	40
Rural high school	75	38	37
Regional differences:			
New England	76	47	44
Mid-Atlantic	74	49	44
West South Central	83	29	26
Mountain	74	28	35
Curricular track:			
General	71	21	23
Academic	83	58	44
Vocational	64	15	22

NOTE: The source from which this tabulation is derived does not indicate the total numbers of students in these samples. Also the data are originally reported as not indicate the actual order in which the courses were taken, only that the students had taken those courses before graduating from high school. To this extent the tabulation forces an archival formalism on the order of course-taking.

SOURCE: Jeffrey A. Owings, *Science Course Taking by 1980 High School Sophomores Who Graduated in 1982* (Washington, DC: U.S. Department of Education, National Center for Education Statistics, April 1986).

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Local response planned to mathematics crisis

The Chronicle of Higher Education

8 February 1989

"Letters to the Editor"

To the Editor:

In response to Edward A. Connor's Opinion concerning declining interest in mathematics ("America's Scientific Future Is Threatened by the Decline in Mathematical Education," January 11), something is being done to turn the tide in this most serious problem facing mathematics educators today.

In East Central Pennsylvania, a group of local administrators, schoolteachers (K–12), college professors, and an industry representative heard Dr. Connor's pleas before they surfaced in print. In May 1988 this group met and decided to address the math crisis locally.

On April 5, 1989, "MathConn '89" will be held at Cedar Crest College, a women's college in Allentown, Pa. On this Mathematics Awareness Day, teachers from approximately 40 schools in a five-county area will bring over 200 seventh- and eighth-grade girls to spend a busy day in activities such as those recommended in the Opinion piece.

These girls will attend group sessions led by successful women in math-related fields, hear two world-renowned women mathematicians, and learn about current and future career possibilities that require mathematics training. . . .

A group effort can do much more than an individual one. "MathConn '89" has come to fruition by pooling all the strengths of its members toward the goals of encouraging girls to pursue math-related careers and of presenting mathematics itself as a fun, vibrant, and integral part of the world of today and the future. . . .

Regina Bruhner
Assistant Professor of Mathematics and Computer Science
Cedar Crest College
Co-chair of "MathConn '89"
Allentown, Pa.

ENGINEERS WEEK, SUNDAY, FEBRUARY 19, 1989

Thwarting the math crisis

By Dr. Regina Baron Brunner
Assistant Professor of Mathematics
and Computer Science
Cedar Crest College

In May 1988, a group of educators from grades K-12, school administrators, college professors, and representatives from business and industry met in a "brainstorming" session at Cedar Crest College in Allentown. The outcome of this meeting was the birth of a local network in the Lehigh Valley area of east central Pennsylvania. This support network has as its purpose the encompassing goal of creating in the future a math center for research, teaching, and learning.

MathConn at CCC (Cedar Crest College) developed in response to a need in current society to address the problems of today's present and future teachers and those of today's students. The schools, in cooperation with business, industry, and the community as a whole must encourage mathematical growth and interest at all levels for the United States to upgrade its mathematics education programs.

High technology cannot afford to overlook the power it possesses to encourage youngsters to plan for a career in math related fields. For example, are women being used to their full potential? How many women are employed in math related fields? What percentage of women have Ph.D.'s in such fields?

MathConn at CCC lacked funds when started yet we began to plan a Mathematics Awareness Day for April 5, 1989 to be held at Cedar Crest College. Via our developing network, we were rewarded with very strong school support in our area. We contracted various book publishers, and they also have given support to our project by providing various gifts in kind.

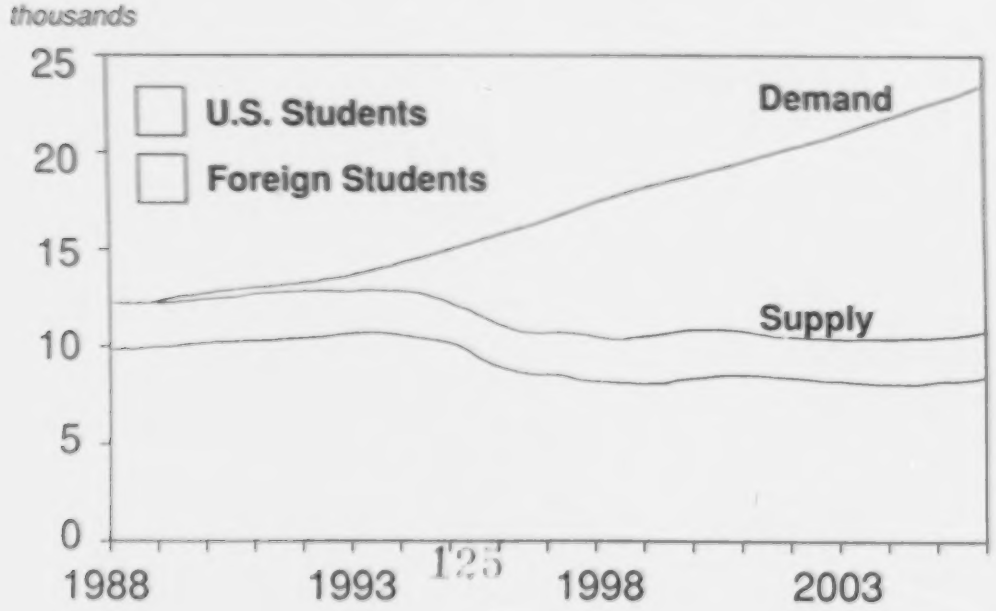
MathConn 89 will consist of many varied events. Each girl will take part in the Mary Ellen Rudin Discovery Problem Session named in honor of the mathematics professor at University of Wisconsin Madison. Dr. Rudin, a set theorist, topologist noted for ability to construct counterexamples, exemplifies the spirit of enthusiastic problem solving and mathematical fun. Also, each girl will attend discussions by successful women in math related careers. Hopefully, exposure to positive role models and the exciting world of current, vibrant math related activities will encourage interest in mathematics itself and in math related careers.

People do care and do want to help, but you have to ask. MathConn 89 has mushroomed into a spectacular day beyond any teacher's wildest dreams. Hopefully, others also will be encouraged to try to turn their bright ideas into reality. Such "grass roots" movements will lead math educators into viable, workable solutions to address and to relieve the perplexing current crisis in math education.

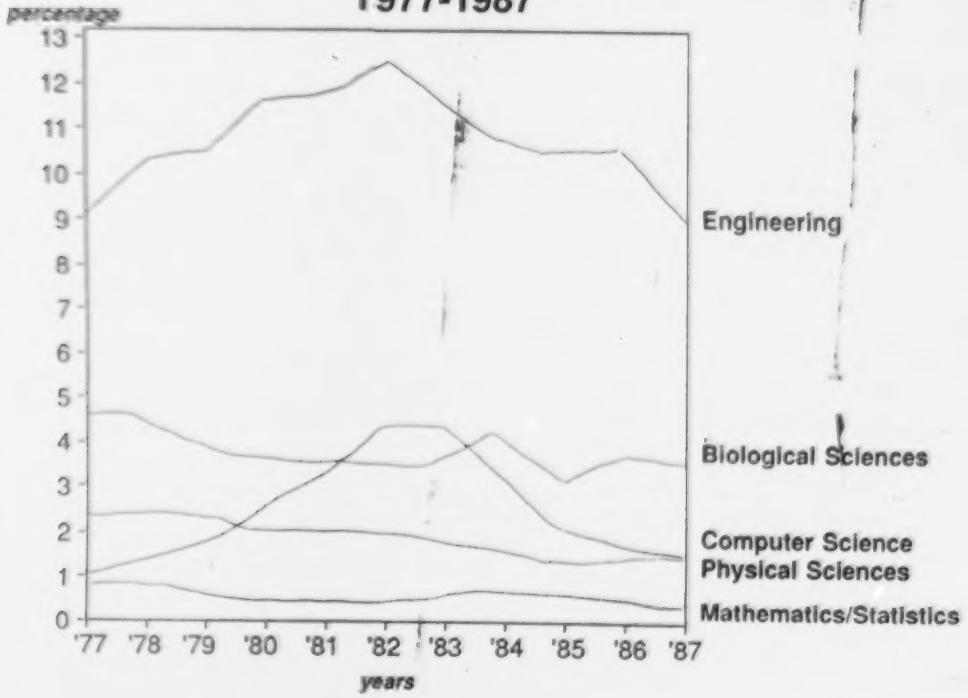
Excellence in Science, Mathematics and Technology Education Act of 1990

- National Network of 9 Regional Science, Mathematics, and Technology Education Consortiums
- National Clearinghouse for Science, Mathematics, and Technology Education Materials
- Federal Support for Informal Science Education

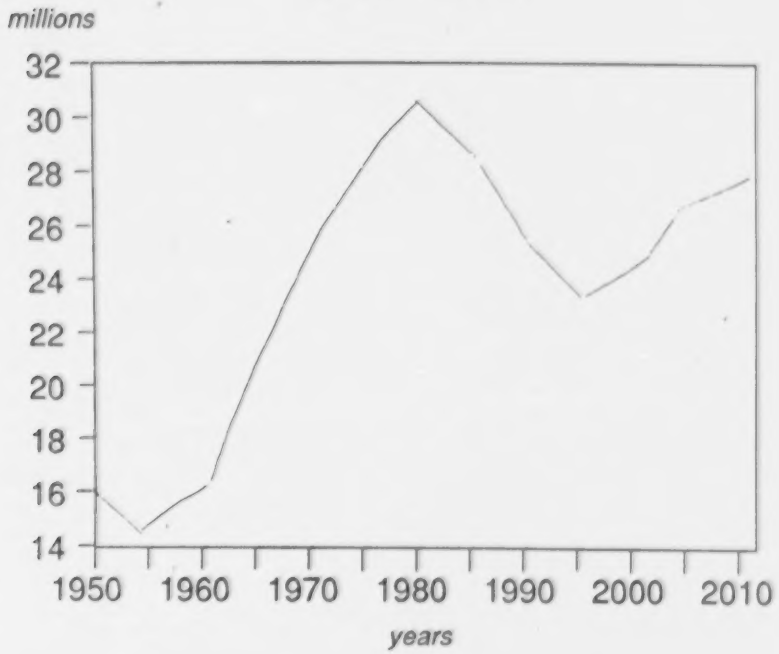
Science and Engineering Ph.D.s
Future Supply and Demand



Student Interest in Science and Engineering 1977-1987



18 to 24-Year-Olds in the U.S. Population
1950 - 2010



SAGAN

America's getting an F in science and math. So what?

Why We Need To Understand Science

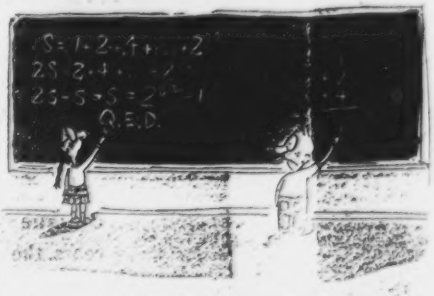
AS I GOT OFF THE plane, he was waiting for me, holding up a sign with my name on it. I was on my way to a conference of scientists and TV broadcasters, and the organizers had kindly sent a driver.

"Do you mind if I ask you a question?" he said as we waited for my bag. "Isn't it confusing to have the same name as that science guy?"

It took me a moment to understand. Was he pulling my leg? "I *am* that science guy," I said. He smiled. "Sorry. That's my problem. I thought it was yours too." He put out his hand. "My name is William F. Buckley." (Well, his name wasn't *exactly* William F. Buckley, but he did have the name of a contentious TV interviewer, for which he doubtless took a lot of good-natured ribbing.)

As we settled into the car for the long drive, he told me he was glad I was "that science guy"—he had so many questions to ask about science. Would I mind? And so we got to talking. But not about science. He wanted to discuss UFOs, "channeling" (a way to hear what's on the minds of dead people—not much it turns out), crystals, astrology . . . He introduced each subject with real enthusiasm, and each time I had to disappoint him: "The evidence is crummy," I kept saying. "There's a much simpler explanation." As we drove on through the rain, I could see him getting glummer. I was attacking not just pseudoscience but also a facet of his inner life.

And yet there is so much in real science that's equally exciting, more mysterious, a greater intellectual challenge—as well as being a lot closer to the truth. Did he know about the molecular building blocks of life sitting out there in the cold, tenuous gas between the stars? Had he heard of the footprints of our ancestors found in 4-million-year-old volcanic ash? What about the raising of the Himalayas when India went crashing into Asia? Or how viruses subvert cells, or the radio search for extraterrestrial intelligence or the ancient civilization of Ebla? Mr. "Buckley"—well-spoken, intelligent, curious—had heard virtually nothing of modern science. He *wanted* to know about science. It's just that all the science got filtered out before it reached him. What the society permitted to trickle through was mainly pretense and confusion. And it had never taught him how to distinguish real science from the cheap imitation.



Ignorance of science threatens our economic well-being, national security and the democratic process. We must do better.

All over America there are smart, even gifted, people who have a built-in passion for science. But that passion is unrequited. "A recent survey suggests that 94% of Americans are "scientifically illiterate."

Carl Sagan

A prescription for disaster. We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology. This is a clear prescription for disaster. It's dangerous and stupid for us to remain ignorant about global warming, say, or ozone depletion, toxic and radioactive wastes, acid rain. Jobs and wages depend on science and technology. If the United States can't manufacture, at high quality and low price, products people want to buy, then industries will drift out of the United States and transfer a little prosperity to another part of the world. Because of the low birthrate in the '60s and '70s, the National Science Foundation projects a shortage of nearly a million professional scientists and engineers by 2010. Where will they come from? What about fusion, supercomputers, abortion, massive reductions in strategic weapons, addiction, high-resolution TV, airline and airport safety, food additives, animal rights, superconductivity, Midgetman vs. rail-garrison MX missiles, going to Mars, finding cures for AIDS and cancer? How can we decide national policy if we don't understand the underlying issues?

I know that science and technology

AGAIN

are not just cornucopias pouring good deeds out into the world. Scientists not only conceived nuclear weapons; they also took political leaders by the lapels, arguing that *their* nation—whichever it happened to be—had to have one first. And then they arranged to manufacture 40,000 of them. Our technology has produced thalidomide, CFCs, Agent Orange, nerve gas and industries so powerful they can ruin the climate of the planet. There's a reason people are nervous about science and technology.

And so the image of the mad scientist haunts our world—from Dr. Faust to Dr. Frankenstein to Dr. Strangelove to the white-coated loonies of Saturday morning children's TV. (All this doesn't inspire budding scientists.) But there's no way back. We can't just conclude that science puts too much power into the hands of morally feeble technologists or corrupt, power-crazed politicians and decide to get rid of it. Advances in medicine and agriculture have saved more lives than have been lost in all the wars in history. Advances in transportation, communication and entertainment have transformed the world. The sword of science is double-edged. Rather, its awesome power forces on all of us, including politicians, a new responsibility—more attention to the long-term consequences of technology, a global and [illegible] generational perspective, alertness to avoid easy appeals to nationalism and chauvinism. Mistakes are becoming too expensive.

Science is much more than a body of knowledge. It is a way of thinking. This is central to its success. Science requires us to let the facts in, even when they don't conform to our preconceptions. It compels us to carry alternative hypotheses in our heads and see which one best matches the facts. It urges on us a fine balance between skepticism and open-mindedness to new ideas, however heretical, and the most rigorous critical scrutiny of everything—even cherished established wisdom. We need wide dissemination of this kind of thinking. It works. It's an essential tool for a democracy in an age of change. Our tool is not and so much more accessible than its deepest gifts to understanding and power.

How bad is it? Years ago Time magazine [illegible]

cial, "finds one newspaper headline: 'We Stink in Science'." Less than half of all Americans know that the Earth revolves around the Sun (it takes a year to do it)—a fact established a few centuries ago. In tests of science IQ, year-olds in many world regions, the U.S. ranked dead last in algebra, the chemical tests, the U.S. kids averaged 41% and their Taiwanese counterparts 78%. In my book, 78% is pretty good—it corresponds to a C+—and maybe even a B—. 41% is an F. In chemistry it's [illegible] countries in my survey (Finland did worse than the U.S. Computer-wise, Britain, Singapore and Hong Kong were all [illegible] scale, a 425 [illegible] ation 18-year-olds knew just as much chemistry as a select 1% of American high school seniors in their second chemistry course, and most of them in "advanced" programs). The best of 20 fifth-grade classrooms in Minneapolis was outscored by every one of 20 classrooms in Sendai, Japan, and 19 out of 20 in Taipei. Taiwan, South Korean students were far ahead of American students in all aspects of mathematics and science, and 13-year-olds in British Columbia (in Western Canada) outpaced their U.S. counterparts across the boards (in some areas they did better than the Koreans). Of the U.S. kids, 22% say they dislike school; only 8% of the Koreans do. Yet two-thirds of the Americans, but only a quarter of the Koreans, say they are "good at mathematics."

Why we're flunking. How do British Columbia, Japan, Britain and Korea manage so much better than we do?

During the Great Depression, teachers enjoyed job security, good salaries, respectability. Teaching was an admired profession, partly because learning was widely recognized as the road out of poverty. Little of that is true today. And so science (and other) teaching is too often incompetently or uninspiringly done, its practitioners, astonishingly, having little or no training in their subjects—sometimes themselves unable to distinguish science from pseudoscience. Those who do have the training often get higher-paying jobs elsewhere.

We need more money for teachers' training and salaries, and for laboratories—so kids will get hands-on experience rather than just reading what's in the books. But all across America, school-bond issues on the ballot are regularly defeated. U.S. parents are much more satisfied with what their children are learning in science and math than are, say, Japanese and Taiwanese parents—whose children are doing so much better. No one suggests that property taxes be used to provide for the military budget, or for agriculture, or for cleaning up toxic wastes. Why just education? Why not support it from general taxes on the local and state levels? What about a special education tax for those industries with special needs for technically trained workers?

AGAIN

...average high school student spends 1.5 hours a week on homework. The total time devoted to studies, in and out of the classroom, is about 20 hours a week. Japanese fifth-graders average 33 hours a week.

But most American kids aren't stupid. Part of the reason they don't study hard is that they've received a tangible benefits when they do. Competency (that actually knowing the stuff) in verbal skills, mathematics and science these days doesn't increase earnings for average young men in their first eight years out of high school—many of whom take service rather than industrial jobs.

In the productive sectors of the economy, though, the story is different. There are furniture factories, for example, in danger of going out of business—not because there are no customers but because few entry-level workers can do simple arithmetic. A major electronics company reports that 60% of its job applicants can't pass a fifth-grade math test—and that's an American, not a Korean, fifth-grade test. The United States already is losing some $25 billion a year (mainly in lost productivity and the cost of remedial education) because workers, to too great a degree, can't read, write, count or think. Parents should know that their children's livelihoods may depend on how much math and science they know. Now, while the kids are in school, is the time for them to learn. Parents might encourage their schools to offer—and their kids to take—comprehensible, well-taught advanced science courses. They might also limit the amount of mind-numbing TV their children watch.

What we can do. Those in America with the most favorable view of science tend to be young, well-to-do, college-educated white males. But three-quarters of new American workers between now and 2001 will be women, nonwhites and immigrants. Discrimination against them isn't only unjust, it's also self-defeating. It starves the American economy of desperately needed skilled workers.

Black and Hispanic students are doing better in standardized science tests now than in the late 1960s, but they're the only ones who are. The average math gap between white and black U.S. high school graduates is still huge—two to three grade levels; but the gap between white U.S. high school graduates and those in, say, Japan, Canada, Great Britain or Finland is more than twice as big. If you're poorly motivated and poorly educated, you won't know much—no mystery here. Suburban blacks with college-educated parents do just as well in college as suburban whites with college-educated parents. Enrolling a poor child in a Head Start program doubles his or her chances to be employed later in life; one who completes an Upward Bound program is four times as likely to get a college education. If we're serious, we know what to do.

What about college and university? There are obvious steps similar to what should be done in high schools: salaries for teachers that approach what they could get in industry; more scholarships, fellowships and laboratory equipment; laboratory science courses required of everyone to graduate; and special attention paid to those traditionally steered away from science. We should also provide the financial and moral encouragement for academic scientists to spend more time on public education—lectures, newspaper and magazine articles, TV appearances. This requires scientists to make themselves understandable and fun to listen to. To me, it seems strange that some scientists, who depend on public funding for their research, are reluctant to explain to the public what it is that they do. Fortunately, the number of scientists willing to speak to the public—and capable—has been increasing each year. But there are not yet nearly enough.

Virtually every newspaper in America has a daily astrology column. How many have a daily science column? When I was growing up, my father would bring home a daily paper and consume (often with great gusto) the baseball box scores. There they were, to me dry as dust, with obscure abbreviations (W, SS, SO, W-L, AB, RBI), but they spoke to him. Newspapers everywhere printed them. I figured maybe they weren't too hard for me. Eventually I too got caught up in the world of baseball statistics. (I know it helped me in learning decimals, and I still cringe a little when I hear that someone is "batting a thousand." But 1.000 is not 1,000. The lucky player is batting one.)

Or take a look at the financial pages. Any introductory material? Explanatory footnotes? Definitions of abbreviations? None. It's sink or swim. Look at those acres of statistics! Yet people voluntarily read the stuff. It's not beyond their ability. It's only a matter of motivation. Why can't we do the same with math, science and technology?

By far the most effective means of raising interest in science is television. There's lots of pseudoscience on TV, a fair amount of mediocre and technobabble, but hardly any science—especially on the three big commercial networks, whose executives think science programming means ratings declines and lost profits, and nothing else matters. Why in all America is there no TV drama that has as its hero someone devoted to figuring out how the Universe works?

Starting projects in science and technology attract and inspire youngsters. The number of science Ph.D.s peaked around the time of the Apollo program and declined thereafter. This is an important potential side-effect of such projects as sending humans to Mars, or the Superconducting Supercollider to explore the fine structure of matter, or the program to map all human genes.

Every now and then, I'm lucky enough to teach a class in kindergarten or the first grade. Many of these children are curious, intellectually vigorous, ask provocative and insightful questions and exhibit great enthusiasm for science. When I talk to high school students, I find something different. They memorize "facts." But, by and large, the joy of discovery, the life behind those facts, has gone out of them. They're worried about asking "dumb" questions; they're willing to accept inadequate answers; they don't pose follow-up questions; the room is awash with sidelong glances

continued

SAGAN

to judge, second by second, the approval of their peers. Something has happened between first and 12th grade, and it's not just puberty. I'd guess that it's partly peer pressure not to excel (except in sports); partly that the society teaches short-term gratification; partly the impression that science or math won't buy you a sports car; partly that so little is expected of students; and partly that there are so few role models for intelligent discussion of science and technology or for learning for its own sake.

But there's something else. Many adults are put off when youngsters pose scientific questions. Children ask why the Sun is yellow, or what a dream is, or how deep you can dig a hole, or when is the world's birthday or why we have toes. Too many teachers and parents answer with irritation or ridicule, or quickly move on to something else. Why adults should pretend to omniscience before a 5-year-old, I can't for the life of me understand. What's wrong with admitting that you don't know? Children soon recognize that somehow this kind of question annoys many adults. A few more experiences like this, and another child has been lost to science.

There are many better responses. If we have an idea of the answer, we could try to explain. If we don't, we could go to the encyclopedia or the library. Or we might say to the child: "I don't know the answer. Maybe no one knows. Maybe when you grow up, you'll be the first to find out."

But mere encouragement isn't enough. We must also give children the tools to winnow the wheat from the chaff. I'm haunted by the vision of a generation of Americans unable to distinguish reality from fantasy, hopefully clutching their crystals for comfort, unequipped even to frame the right questions or to recognize the answers. I want us to rescue Mr. "Buckley" and the millions like him. I also want us to stop turning out leaden, incurious, unimaginative high school seniors. I think America needs, and deserves, a citizenry with minds wide awake and a basic understanding of how the world works.

Public understanding of science is more central to our national security than half a dozen strategic weapons systems. The submediocre performance of American youngsters in science and math, and the widespread adult ignorance and apathy about science and math, should sound an urgent alarm. TC

Carl Sagan teaches and does research at Cornell University. His Emmy and Peabody Award-winning TV science series COSMOS has been seen in more than 60 countries by 400 million people. Videocassettes of all 13 episodes will be available in stores later this year from Turner Home Entertainment. The accompanying book, "Cosmos," is the best-selling science book ever published in the English language.

NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS

Statement
on
The **MATHCOUNTS** Program

as it relates to

Science and Mathematics Education

Prepared By
The National Society of Professional Engineers

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This statement describes the MATHCOUNTS program, a national math competition for seventh and eighth grade students designed to increase students' interest and ability in mathematics and to heighten public awareness of the importance of math. The National Society of Professional Engineers (NSPE) is pleased to submit this statement to the Senate Committee on Governmental Affairs for its hearing on U.S. science and mathematics education.

NSPE is an interdisciplinary society of 75,000 engineers and engineering students in 535 chapters and 54 state and territorial societies employed in all technical disciplines and all areas of practice, including education, industry, government, private practice and construction.

The need for improvements in U.S. math and science education has been well documented. In math skills, American students trail discouragingly behind their counterparts in other parts of the world. If the United States expects to be a strong leader in the global economy, it is critical that we start now to ensure a technically qualified work force. To do so, we must challenge all aspects of our educational system, from curricula to teacher training and compensation.

Similarly, we must find innovative approaches to promote math and science as exciting and challenging experiences that lead to rewarding career opportunities. MATHCOUNTS was created in 1983 in

response to the declining level of math literacy in America. As noted in 1983 by Ronald Reagan, "We must create a new awareness in our young people to meet our country's technological needs of today and tomorrow. We need mathematicians, scientists and engineers. Programs such as MATHCOUNTS can help to encourage our young people to develop their math skills."

Analogous in concept to the national spelling bee, MATHCOUNTS is a national seventh and eighth grade coaching and competition program that fosters enthusiasm and prestige for math achievement. The program's success has been possible through the thousands of corporations, individuals and foundations that support the program at the local and state levels. MATHCOUNTS has received two presidential citations as an outstanding private sector initiative.

It is the first nationwide program of its kind, combining the efforts of education, business, government and the technological community to promote math excellence among junior high school students. MATHCOUNTS is a cooperative project of NSPE, the CNA Insurance Companies, the Cray Research Foundation, General Motors Foundation, the National Council of Teachers of Mathemathics and NASA.

The program has three primary objectives. 1) to improve the quality of math education and to broaden mathematics curricula in seventh and eighth grades throughout the United States; 2) to

elevate the prestige associated with achievement in mathematics; and 3) to increase awareness among parents, educators and the general public of the importance of mathematics in our technological society.

The program builds skills, promotes strategic problem-solving and brings students together for a lively exchange of mathematical ideas through competition. MATHCOUNTS is directed at students at an age when they are formulating attitudes about math and technology--when they can still elect to take college math courses in high school to prepare them for future technical careers. Through MATHCOUNTS, parents, educators and the general public all are made aware of career opportunities in math.

Today, MATHCOUNTS programs exist in all 50 states, the District of Columbia, Guam, Puerto Rico, the Virgin Islands, the Department of Defense and the State Department school system. Each year, 7,500 schools nationwide--twice as many since 1983--register to participate in over 450 local and state competitions. Since the program began, over 3 million students have been involved in MATHCOUNTS. We owe this success to the commitment of MATHCOUNTS sponsors and the enthusiasm and hard work of more than 15,000 volunteers.

The competition phase of MATHCOUNTS begins in the schools in the form of a qualifying test. Students are coached in everything

from basic arithmetic skills to math logic, probability and statistics, linear algebra and polynomials. Between September and the national competition in the spring, students and teachers work together in quizzes and drills to develop teamwork and skill. They are then ready to advance to regional and state competitions which could lead them to Washington, D.C., and the national math finals.

The MATHCOUNTS program is closely tied with the National Council of Teachers of Mathematics (NCTM) in development of program materials. Each September, teachers at thousands of participating schools receive a MATHCOUNTS handbook which contains study guides and practice drills. These materials include the most recent developments in math education. Question writers are experts in math and are chosen by the NCTM. Each year MATHCOUNTS selects a special topic that usually is not taught in junior high school, such as transformational geometry and probability, which gives students an opportunity to explore subjects to which they would not normally be exposed.

The MATHCOUNTS program allows students to be identified as "winners" in an academic event. Competitors are referred to as "mathletes," and, as in sports programs, individuals and teams receive trophies, plaques or certificates at all levels of competition. Winning students and coaches travel free to the national competition. An exciting part of winning at the national level is an expense-paid trip to view a space shuttle launch.

Through publicity, community involvement and a broad base of participation, MATHCOUNTS increases public awareness of the importance of math. Major sponsors and NSPE chapters cooperate to publicize MATHCOUNTS across the nation. As a result of these efforts, several governors have declared a "MATHCOUNTS Week" in their states. In order to reach the most students, MATHCOUNTS is available to all junior high schools, regardless of their size or financial status. There is no registration fee for schools or students, and coaching materials are provided at no charge.

Perhaps the best measure of MATHCOUNTS' success is to hear directly from those involved in the program. Teachers consistently report that confidence-building is one of the greatest benefits of MATHCOUNTS. Students who normally might not receive attention for their math achievements are rewarded for success in math just as athletes are recognized for excellence in sports. An important aspect of the program is that all students benefit from the coaching sessions, not just those who are likely to compete.

Still a relatively young program, MATHCOUNTS is committed to helping reverse the declining level of math achievement in the nation's schools. The first mathletes of six years ago are now in college. We are beginning to track these students to determine their career paths and the impact MATHCOUNTS has had on their choices.

MATHCOUNTS will focus increasingly on the development of minority incentive programs, particularly in inner city school systems. Recognizing that the majority of students who enter math-oriented careers are male, MATHCOUNTS makes a special effort to involve more females in the program. In many states, members of the Society of Women Engineers conduct MATHCOUNTS coaching sessions. As role models, these women encourage girls to pursue math-related careers. MATHCOUNTS also will focus more on the development of coaching workshops to help teachers get the most out of MATHCOUNTS' programs and materials.

The United States must have a technically competent work force to succeed in today's international marketplace. As noted in Workforce 2000 by William B. Johnson and Arnold H. Packer, "Very few new jobs will be created for those who cannot read, follow directions, and use mathematics." To this end, we must make improvements now in math and science education. By focusing on the fun of learning math, MATHCOUNTS is striving to do its part.

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To serve the public, the profession and the NSPE membership. To advocate the application of engineering knowledge and skills in the public interest and in accordance with the highest ethical standards. To influence technical policy. To foster public understanding of the role of engineering in society and the licensing of engineers to protect public health, safety and welfare. To promote the professional, social and economic interests of NSPE's individual members.

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